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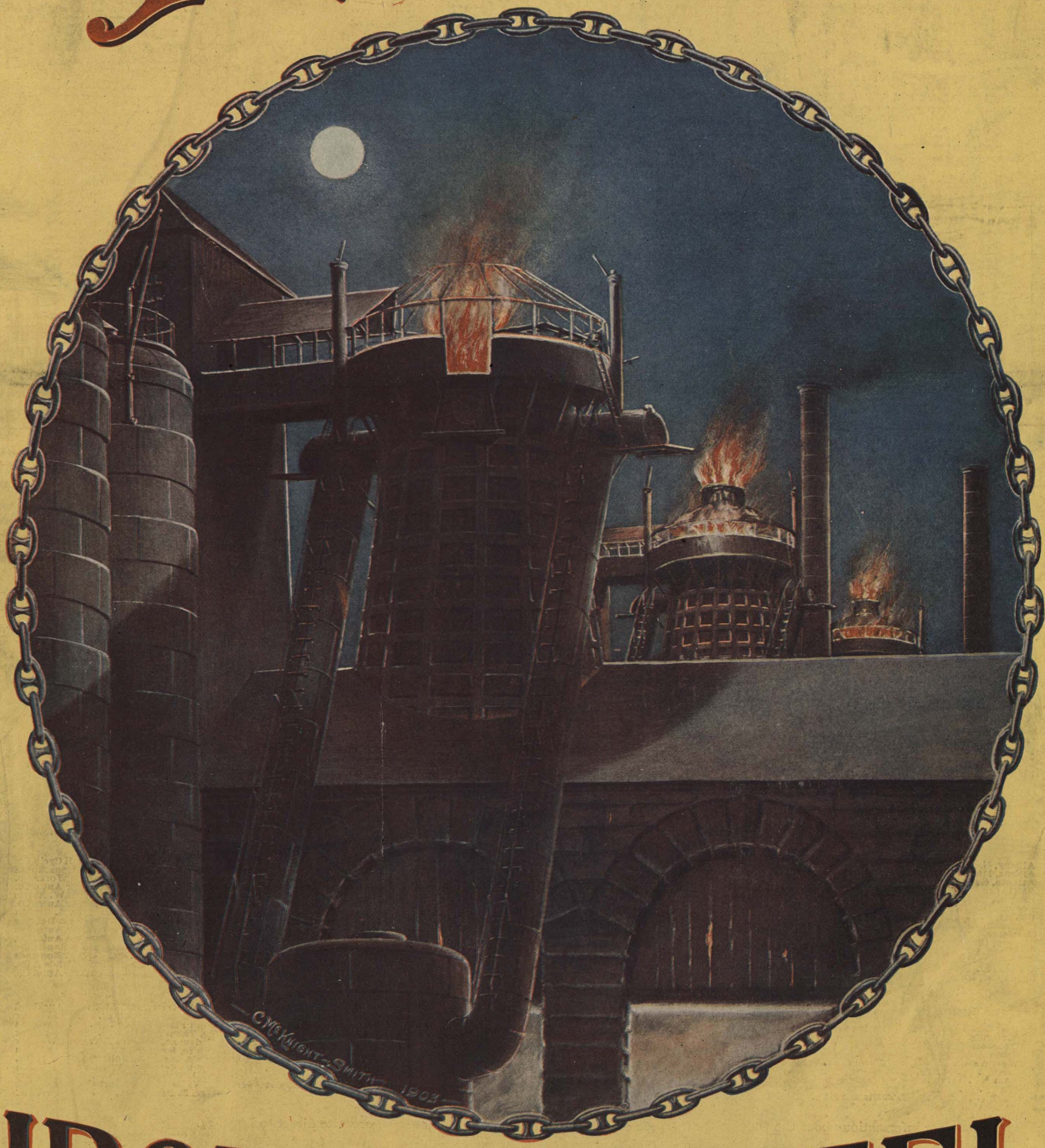

IRON AND STEEL

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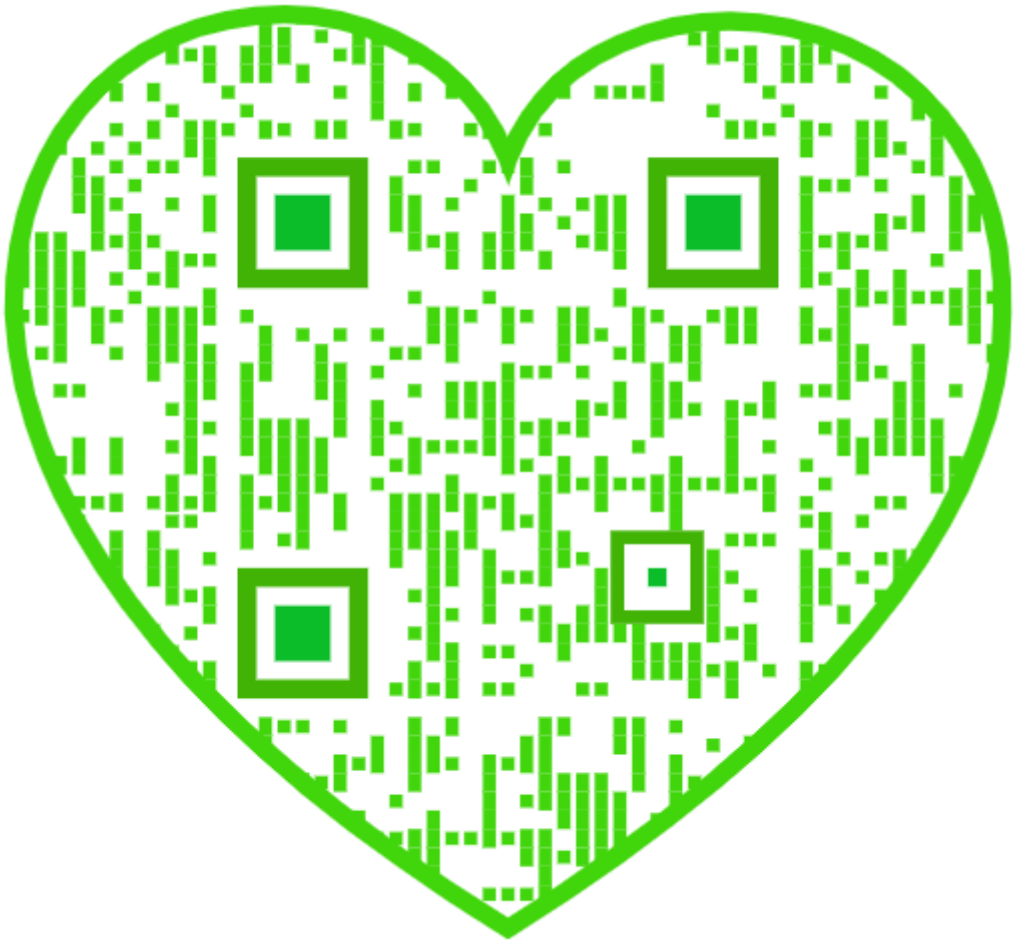
PRICE 10 CENTS



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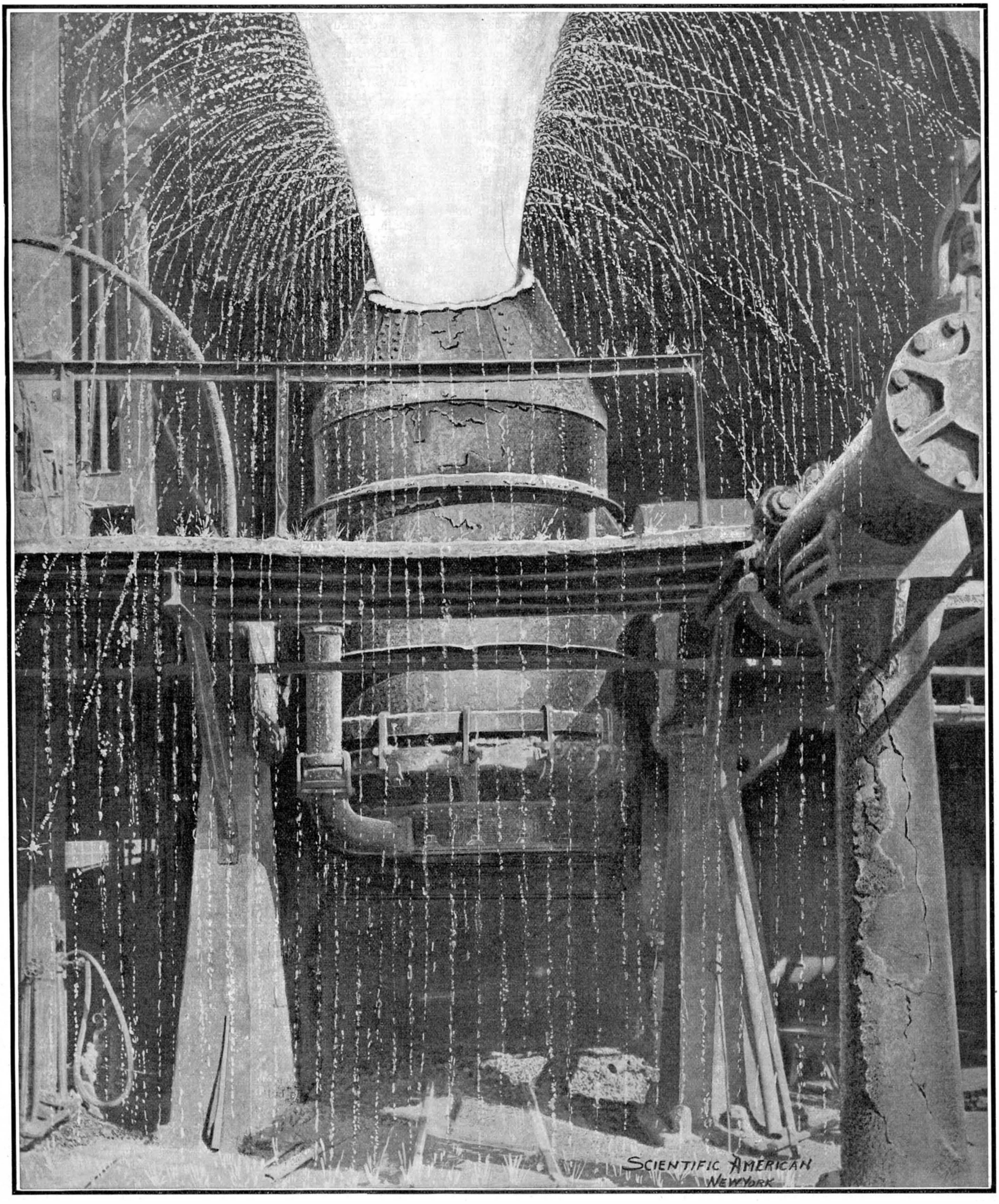

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A BESSEMER CONVERTER IN FULL BLAST.

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NEW YORK, SATURDAY, DECEMBER 12, 1903.

The editor is always glad to receive for examination illustrated articles on subjects of timely interest. If the photographs are *sharp*, the articles *short*, and the facts *authentic*, the contributions will receive special attention. Accepted articles will be paid for at regular space rates.

HISTORICAL.

UPON a certain summer's day in the year 1755, there might have been witnessed the advance of a small detachment of British and Colonial troops, not much over a thousand strong, through the dense forests that lined the banks of the Monongahela River a few miles above the point where it merges with the Allegheny. The objective point of the expedition was a small fort at the confluence of these rivers, which formed one of the most important links in that chain of military posts and trading stations, which the restless and far-seeing energy of the French colonial government had strung out between the mouths of the St. Lawrence and the Mississippi, by way of the Great Lakes, the Ohio, and the Mississippi Valley. In the van of this little army, bearing himself with a confidence born of much successful warfare in other lands under less difficult conditions, and heedless of the warnings of his young colonial aide-de-camp George Washington, who had command of the rear guard, was Gen. Braddock. Advancing in a close formation, which was better suited to the open spaces of Continental battlegrounds than to the all-but-impenetrable forests of the American frontier, the devoted band marched right into an ambush of the French regulars and their Indian allies, and was quickly cut to pieces. Braddock was killed, and Col. Washington, his military coat pierced more than once by the bullets of the French sharpshooters, barely succeeded in carrying the shattered remnants of the force back over the Alleghenies into Colonial territory. The political and military considerations that prompted that disastrous expedition were worthy of a better fate; and, indeed, subsequent history has proved that in endeavoring to capture Fort Du Quesne and break the bounds which the French were endeavoring to set to the westward development of the British colonies, our forefathers had taken a just view of the situation. To-day the objective point of the expedition forms the site of Pittsburg, one of the greatest centers of industrial activity in the world; while hidden among the back streets of the city, and rescued from destruction and preserved through the care and munificence of a local historical society, may still be found Fort Du Quesne, or rather its immediate successor Fort Pitt. A few miles up the river, at the town of Braddock and on the identical spot where the battle occurred, is to be found one of the greatest steel works in the world; while for many a mile along those very banks of the Monongahela where Braddock laboriously cut his way through the woods, is to be found the most wonderful aggregation of coking ovens, blast furnaces, and rolling mills in the world. Although just now we are concerned merely with the history of the development of these industries, we may be pardoned a reference to the fact that in St. Louis, five hundred miles to the westward of the Braddock battlefield, the great Republic which has sprung from that strip of colonies that fringed the Atlantic seaboard in 1755, is just now preparing to celebrate the one hundredth anniversary of its acquisition from France of the vast territories from which that country sought to bar the early colonials out.

In selecting a point of beginning for a brief survey of the rise and growth of the iron and steel industry in this country, we cannot do better than go to the records of Pennsylvania, from which we shall learn that in the year 1786 the Legislature lent a certain Mr. Humphries the sum of three hundred pounds for five years, to enable him to make steel "as good as in England." Progress must have been slow; for a quarter of a century later, or in the year 1810, the total production of pig iron in the United States was but 53,908 tons; and of this, less than one thousand tons was made into steel. In 1842 the total was only 215,000 tons; and in 1861, during the great civil war, it was still far below the million mark, being only 653,164 tons. In 1864 the total production had risen for the first time to a little over one million tons. Up to this time steel was looked upon as a very special product, the methods of production being costly and the total output relatively small. But in the year 1864 there was invented and demonstrated in the mother country what was, and will ever be, the greatest invention in the history of iron and steel—the Bessemer converter. By this device, it was made possible during an operation of an extremely simple and inexpensive character, and in a few minutes' time, to convert common cast iron into steel. Steel, from costing as high as six or seven cents a pound for the common grades, began steadily to decrease in cost, until in the closing year of the nineteenth century steel billets, in lots of a hundred thousand tons, came to be sold at the rate of "three pounds of steel for two cents." The entrance of the Bessemer converter marked the close of the Iron Age, and from this time on steel became the standard material of construction in all but a few limited classes of work. It was not long before the Bessemer process was introduced into this country, and this fact, coupled with the period of general commercial prosperity which followed upon the close of the civil war, stimulated the development of the iron and steel industry so greatly that by the year 1872 the total production of pig iron had increased to 2,548,713 tons. In 1880 the total had climbed to 3,835,191 tons, and in the following year it had risen to a little over 4,000,000 tons. By the close of this decade the production of pig iron had doubled, the total output in 1891 having reached the wonderful figure of 8,279,870 tons. During the last decade of the century there was another increase of about one hundred per cent, during which the total output of pig iron passed far beyond that of our nearest competitor, Great Britain, reaching in 1901 the enormous output of 15,878,354 tons; while for the following year the production climbed yet higher, reaching a total of 17,821,307 tons. Toward the close of the century there was introduced a method of steel manufacture which gave early promise of being a rival to the Bessemer converter, a promise which has been so far fulfilled, that it may be said without any exaggeration that the age of Bessemer steel is drawing to its close, and that open-hearth steel is destined ultimately to be the all-but-exclusive product of the industry. The open-hearth furnace has the advantage, especially in the United States, that whereas the Bessemer process requires for its successful working the use of ores that are comparatively free from phosphorus, ores that are high in phosphorus can be used successfully in the open-hearth furnace. Moreover, for reasons which are given later in the present issue, it is possible to produce a grade of steel in the open hearth that is so superior to Bessemer steel as to more than compensate for the additional cost of manufacture. The advantages of the process and product were quickly recognized by both ironmasters and engineers; and it is becoming increasingly common to see open-hearth steel called for in the specifications of the more important classes of construction.

We may look with pardonable pride upon the growth of an industry for which there is no parallel in the history of the world; and the more so as this growth is a true index of the general material prosperity of the country at large. For it must be remembered that, great as is the total production of iron and steel, it has proved, during the last year or two, so far short of the home demand, that we have been obliged to call upon foreign manufacturers to supply the deficit.

SECRETS OF OUR SUPREMACY IN IRON AND STEEL.

In looking for the causes which underlie the supremacy of the United States in the steel and iron trade, honesty and gratitude alike demand that first place be given to the marvelous natural resources of the country, for which there is no parallel anywhere in the world. Not only has nature provided stores of iron ore, coal, and limestone in lavish abundance, but the supply itself is easy of recovery, from its native beds, and advantageously placed for the transporting of its various elements to a common center; while the materials are of a quality that could scarcely be surpassed for economy of handling and treatment in mine, furnace, and mill. But although the fundamental secrets of our success are to be found in natural conditions, too much cannot be said in praise of the intelligence and skill with which the American ironmaster has risen to his opportunities. It is to the remarkable ingenuity shown in the production of labor-saving machinery that much of the cheapening of the cost of production is due; to say nothing of the broad administrative ability shown by the management of the great steel and iron works, in laying out the component parts of their establishments in such a way that the heavy tonnage which passes through these plants day by day shall proceed from the crude material to the finished product with the least possible amount of handling and trans-shipment. Lastly our iron and steel men, early in the history of the development of the industry, perceived and acted upon the fundamental economic fact that, for the cheap production of iron and steel, magnitude of operations and combinations of capital are essential.

First then, we must recognize the lavish hand with which Nature prepared the way for our industrial triumphs, by accumulating along the southern and western shores of Lake Superior those vast beds of iron ore, which are not only the most extensive in the world, but are so placed that the labor of excavating and loading for shipment is practically nothing. The ore, which is extremely rich, sixty per cent of it being iron, lies practically at the surface of the ground; and it is so loose and friable that all that is necessary for its recovery is to run in a train of cars, set a steam shovel at work, and load the material directly onto the cars. This work has actually been done at the rate of 5,800 tons in ten hours, and this with the labor of but eight men at a cost of five cents only per ton for labor. The supply is enormous, a single corporation having recently estimated its holdings at 500,000,000 tons, valued at as many million dollars. These vast and easily-recovered supplies, however, would have a limited value, were there not available a proportionate supply of coking coal; and this has been provided with an equally lavish hand in the famous Connellsville district, where a single coke company on entering into one of the great industrial combinations of the past few years, stated that it owned 40,000 acres of coal lands in this region, and 11,000 coke ovens. Within easy reach of the coal district there are also large quarries of limestone, the third of the three constituents in the charge of a blast furnace.

But the mere existence of these natural supplies of the raw materials of manufacture would not in itself be sufficient to account for the marvelous growth of the iron and steel industry in America. The raw materials must be brought together to some common center, and the transportation of this enormous tonnage, the frequent handling and trans-shipment that is necessary, must be done with the least possible amount of expense, if the American ironmaster is to start with anything like an even chance in competition with European manufacturers; for these are not under the necessity of transporting their materials over a thousand miles of distance, before they can smelt them in the blast furnace. Now, here it is that man has so ably co-operated with Nature. Acting on the well-established industrial principle that the greater the magnitude of the scale of operations, the less is the cost per ton of the finished product, the machinery and general plant for excavating, handling, and transporting the ore have been built on a colossal scale. At the mines, steam shovels capable of lifting five tons of ore at each stroke will load a 25-ton car in two and a half minutes, or at the rate of 600 tons an hour, and in accordance with the same policy cars have grown to 50 tons in capacity and locomotives to 130 tons in weight. When the ore trains reach Lake Superior special automatic, quick-acting machinery unloads the ore direct into special ore steamers built for this particular work. At the eastern terminal ports similar machinery unloads the ore from steamer to railroad, where again 50-ton cars and 130-ton engines haul the precious mineral in trains of 1,000 tons or more total weight, into the heart of the coal and coke region, where it is finally unloaded by special machinery, at the foot of the blast furnaces.

The ingenuity and resourcefulness shown in the matter of handling and transporting the huge tonnage necessary for the manufacture of over 17,000,000 tons of iron a year, was ably seconded when it came to the matter of recovering the iron in the blast furnaces, and fabricating it into the thousand and one forms in which the finished product is put upon the market. In no single branch of industry has more thought been given to labor saving than in the manufacture of iron and steel. In the first place, to reduce handling and transshipment to a minimum the processes are made as far as possible continuous. The erection of a typical modern steel works will call for a plot of ground which is rather a parallelogram than a square, and there are in the country to-day works that on a width of a quarter of a mile will extend for a mile and a quarter in length. At the upper end will be the stockyard, with its artificial mountains of ore and coke; next the blast furnaces; then the Bessemer converters, or the open-hearth furnaces, as the case may be. Then will come the soaking pits or furnaces for heating the cast ingots. Beyond them, in some cases, will stretch one vast building a thousand feet or more in length, with its blooming rolls and shears, roughing rolls, finishing rolls, and steel saws succeeding each other in orderly succession, until at the end of the building one can see the finished product being loaded onto the cars almost before the last trace of the furnace heat has gone out of it. Moreover, in its long journey through the mills, the material has been rolled and heated and rolled again, positively with no manual labor whatever; and in many of the mills that are notable for the great tonnage that they turn out in a single day, the continuous processes are carried on with such rapidity that the journey of a thousand feet or more through the mills is made on one single heat.

In any summary of the causes of our success in steel

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manufacture, great stress must be laid upon the early and multiplied adaptation of electricity as a motive power in the thousand and one uses to which it has lent itself so admirably. Among other applications that come to mind, there are: the overhead traveling electric crane; the electric charging machine that picks up a box containing a ton of mixture, thrusts it into the furnace, empties and withdraws it; the electric conveyer; the electric elevator for loading the blast furnaces; the electric buggies that receive the heated ingot after it has been lifted from the soaking pits and runs it down to the mill; electric machines for pushing the blooms in at one end of the furnace, and electric tongs for gripping them and pulling them out at the other end. These are a few of the uses of electricity, to say nothing of pneumatic and hydraulic power, that, conjointly with similar exhibitions of ingenuity, forethought, and administrative skill in mine, ship, and railroad, have enabled our manufacturers to sell "three pounds of steel for two cents," while paying the highest wages in the world to labor and returning the princeliest of fortunes to capital.

RECENT DEVELOPMENTS IN GUNS AND ARMOR.

BY JOHN F. MEIGS.

A most striking recent development in guns—and in speaking of guns we usually include the gun-carriage or gun-mount—is the effort now universal to throw the accurate and quick control of the gun into the hands of the people firing it. It may well be wondered that this has not always been a controlling idea in laying out guns and their mounts, but at the present time it is in this direction that the greatest effort is being made. The proof of this is to be seen by a comparison of the guns and mounts made ten or fifteen years ago with those now being made. The latter are arranged much more conveniently, and consequently their rate of fire is much faster. Modern 6-inch guns are being fired from ships eight or ten times in a minute at targets about the size of a ship and a mile distant, and hitting the target at each shot. Of course, doing this from a stable platform on shore would be comparatively easy. The projectile of these guns weighs 100 pounds, the powder charge about 40 to 50 pounds, and the weight of the gun, including all the turning parts, is about 25,000 pounds. This weight must be moved, to keep the sights on the target, by one man, and it will be seen that it is of the greatest importance to lay out all the shafting and gearing with a minimum of friction and lost motion.

With this advance in the convenient layout of the gun and its mount is going on at the present time a steady increase in the weight and length of guns. Six-inch guns, which used to weigh 11,000 pounds, now weigh 18,000 to 20,000 pounds. The weight of the projectile of these guns has not increased, and has remained always 100 pounds, but the velocity at which the projectile leaves the gun has increased from about 2,000 feet per second to from 3,000 to 3,500 feet per second, in consequence of a three or fourfold increase in the charge of powder. It may be argued that this change—that is, the constantly increasing weight of guns of a given caliber—is not a wise one. The great care and attention bestowed upon the convenient and accurate moving of the gun, however, can be nothing but an improvement. The growth and progress of change in artillery construction sometimes seems arbitrary—seems sometimes to be as arbitrary as the fashion in clothes. Old guns made three hundred years ago, which may be seen in the arsenals in this country and in Europe, had about the same shape and were in many respects similar to the guns of to-day. In the intermediate period, say about one hundred years ago, the guns had shrunken up, and become shorter and larger in diameter, with larger bores. We are now returning, or perhaps, more correctly, it should be said we have returned, to the fashions in artillery of three hundred years ago.

There are, of course, many respects in which the modern weapon has a great advantage over the earlier one. It is made of stronger steel, and concentric hoops are shrunken together, whereby the power of the gun to resist internal pressure is materially increased. But perhaps in no place is the advantage more marked than in the better mount or carriage of the present time. These are far better arranged than they used to be, and the consequence is that the guns may be much more rapidly and safely fired.

There is going on at the present time a steady advance in the strength of the metal used in guns. The elastic strength of metal now commonly used in larger guns is about 50,000 pounds per square inch, and in the smaller guns it runs as high as 75,000 pounds per square inch. This, however, is used only as an additional margin of safety, largely because the recoil of guns when fired is so great now, and the reaction thereby set up in the carriage is so severe that nothing would be gained by lightening the gun. Lightening the gun would only mean putting additional weight, and perhaps a weight greater than that saved, in the gun-carriage and foundation. Many are of the opinion that the advance in the strength of gun steel should be pushed further, but it would be hard to do this without lowering to some extent the elongation asked for in the metal at rupture. This now runs in the neighborhood of 18 to 25 per cent, and it could wisely be lowered for the sake of gaining a harder and stronger metal, because the entire operation of the gun is within its elastic limit. When it moves outside of this and becomes permanently enlarged, a comparatively slight enlargement would give warning, and the gun would be laid aside and not used any more.

The subject of the powder—or, as it has been called, the Spirit of Artillery—cannot be overlooked in the examination of guns. In the last few years the use of so-called smokeless powders has become universal. These are all nitro substitution products, and their principal characteristic, from an artillery point of view, is the fact that the entire weight, or very nearly the entire weight, turns into gas. In the older powders only about 60 per cent of the weight was gasified, and the remaining 40 per cent was projected from the gun in the form of dust, and constituted a considerable waste of energy. The point not entirely satisfactory in modern powders is their constancy in pressure and velocity, and stability in storage. It is a question whether under the same conditions of storage they are as stable and safe as the old-fashioned powder. Indeed, there is every reason to believe that they are not as safe or as stable, and they are watched with great care at stated times when stored. Incidentally, this powder gives little or no smoke, which is usually, but not always, an advantage.

This brings us naturally to other articles of great consequence in artillery—namely, projectiles and shell charges. We have now armor-piercing projectiles, deck-piercing projectiles, semi-armor-piercing projectiles, common forged and cast-steel projectiles, cast-iron projectiles, shrapnel, and so on, in endless variety. As the work the gun, whether ashore or afloat, will have to do can be pretty clearly predicted, it would appear as though one, or at most two, kinds of projectiles were enough. These two would naturally have, the one a high penetrative power, and the other a large capacity for internal charge, giving great destructive power when the shell is burst. No one who has not examined carefully the effect of bursting a shell in a closed space can have an idea of its destructiveness. A small 6-pounder shell, of about 2¼-inch diameter, containing 3 or 4 ounces of powder, burst in an ordinary room and breaking into 20 or 30 fragments, would probably destroy everything in the room.

We now come to the matter of protection—or armor. It is a mistake to suppose that protection was first used in either land or naval warfare in modern times. On land, as is well known, earthworks and masonry works of great thickness were used, but it is not so well known that the sides of ships of war of one hundred years ago were in many ways better protected relatively than our present ironclads. The frigate "Constitution," of the war of 1812, was protected against perforation at the waterline, whereby the ship may be destroyed, or perforation of her battery space, by which her gun crews could be destroyed, better than the ships of to-day, taking into account the guns of her time. At present the 12-inch guns, using 850 or 1,000 pound projectiles, are mounted in turrets clothed with 12-inch armor. These turrets can be penetrated by 12-inch guns with anything but a very oblique impact at any distance at which a gun is likely to hit. Similarly, too, the 6-inch guns of ships, or their 7-inch guns, which constitute the next step in the scale, are protected by 6-inch or 7-inch armor, and this armor can be penetrated by a 6-inch gun at as great ranges as it is likely to hit it. This armor is all face-hardened. The front or outside of the armor is glass-hard, while its back is comparatively soft and tough.

The plate in the course of manufacture is supercarbonized, that is, its face is impregnated with an additional amount of carbon, in a way similar to the well-known case-hardening process, whereby the outside face of the plate, when tempered in water, becomes intensely hard. The projectiles used against this armor are hardened at the point, their rear bodies being, as is the rear body of the armor, comparatively soft, and the contest between the plate and the projectile constitutes very largely the modern science of artillery. The velocity of the projectiles is pushed to the utmost by increasing the weight of the charge of powder used to propel them, and in the manufacture of the projectiles it is endeavored to make the point of the projectile very hard and the back soft, but yet not too soft. If the projectiles are hard all over, or similarly if an armor plate is hard all through, they will go to pieces on impact. The tough, comparatively soft, back part of both plate and projectile tends to hold the hard part together. In the last few years the practice of putting soft metal caps on the hard points of projectiles intended to pierce armor has become universal. There are many theories as to why these soft metal caps aid the projectiles in getting through the hard armor, but none of them seems entirely satisfactory. Of the fact, however, that they do increase the penetration of projectiles, there can be no doubt.

In the matter of protection or armor, in the land or coast defenses of this country, the principle of the disappearing gun has been utilized in very large degree. The gun, mounted behind a very thick parapet, rises only for a very short space of time when it is to be fired, and disappears on rocking levers behind the parapet immediately upon firing, and is loaded in the lower position. It will be seen that the protection of such guns is very good, but their rate of fire is lessened. Possibly it is true that the rate of fire of large guns is not materially less on disappearing mountings than on others; but as guns grow smaller, the time occupied in their rising and falling and in aiming them has a greater influence, and their rate of fire is seriously diminished. For such smaller classes of guns in our coast defenses it is planned to use gun shields, which are substantially armor plates covering the gun and its detachment of gunners against hostile fire.

There have grown up in all the countries of Europe, and are growing up in this country, private manufactories that will aid the government in the solution of the various ordnance problems brought forward. In many respects a private organization is more likely to bring forward improvements than is the government service. Not the least of these is the fact that it must continually be bringing things forward. It can live in no other way; and if its staff are well equipped and its measures are wise, it should bring forward many good things—things that are likely to last, and that are in the nature of sound progress, and not merely changes. Only great steel works, having large capital and controlled by directors willing to encourage the development of ordnance in their works, can succeed at this task. It is needless to point out the part the government may play in this development. If the government officers, both those who control law-making and those in the executive branches, do not do what they can to aid such a movement, it is likely that it may fail, and that what might have become a valuable public servant may be destroyed. The history of all countries shows in comparatively modern times—in the last thirty or forty years—the upbuilding of such private ordnance factories. There is no feature of the development of modern ordnance in this country more interesting and important than the evolution and equipment of great manufactories capable of supplying the material necessary for the national defense. We now have many establishments more or less well equipped in various lines, and it is to be earnestly hoped that the public at large, and governmental officers having power directly in the premises, will interest themselves actively in the growth of these. Manufactories producing ordnance and armor, having in hand an extremely specialized branch, and looking only to the government for work of this character, are especially interesting in this connection.

THE FUTURE OF OUR STEEL INDUSTRY.

In the course of a conversation with the late Abram S. Hewitt, who was one of the first to foresee the great proportions which the iron and steel industry in this country was destined to assume, the writer asked him to indicate the one fact which above all others assured the supremacy of the United States. To this he replied, that while other nations might in time equal us in the development of labor-saving machinery, we should always hold a commanding position because of the vast extent of the Lake Superior iron mines, and the extraordinary richness of the deposits. The correctness of this view of the situation can never be disputed. So long as we can shovel up ore, sixty per cent of which is iron, from the surface of the ground and load it onto the cars at the cost of only five cents a ton for labor, we are starting with an economic handicap in our favor which, in the present development of the art of steel making, it certainly seems impossible that our competitors should overcome. Moreover, social and political conditions in foreign countries are such that it is practically impossible for them to organize such combinations of properties as place the largest of our steel corporations at enormous economic advantage in the matter of operation and manufacture. Thus an estimate of the cost to the United States Steel Corporation of turning this iron ore into steel does not include any profits of the railroad in carrying it from mine to dock, or profits on docking facilities, or profits on steamship transportation through the lakes, or profits again of any railroad company in the haul from the Lakes to the Pittsburg furnaces. The possession by this corporation of everything in the way of rich and abundant supplies of raw material, transportation facilities, and up-to-date plant, that is necessary for the production of steel, should be sufficient to render permanent our present supremacy.

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THE MANUFACTURE OF STEEL RAILS.

In an issue devoted to the Iron and Steel Industry, the manufacture of steel rails naturally receives the first consideration, both because the total output greatly exceeds that of any other branch of the steel industry, and because the steel rail has undoubtedly had more to do with the rapid development of this country than any other single product of the steel industry. Moreover, the Edgar Thomson Works, of which the present article treats. are truly representative of the vast scale upon which the steel establishments of the United States are laid down, and of the highly-developed methods of labor-saving to which the cheapness of the product in this country is to be largely attributed. These great works, which stretch for over a mile along the banks of the Monongahela River, at a point not far from the city of Pittsburg, require the services of some 4,000 men, who are continually at work on the manufacture of steel rails. These are turned out at the rate of over 7,000 rails, or nearly 3,000 tons, per day, and the output of the blast furnaces is about 4,250 tons of cast iron per day. Of the furnace output, about 20,000 tons are cast into pig, and 70,000 tons are converted into steel and rolled into rails every month. In a single month the rail mills have turned out as high as 180,000 rails, which varied in weight from 25 to 100 pounds per yard and in length from 30 to 60 feet.

The raw materials of manufacture consist of iron ore, coke, and limestone, in the proportions of 2 pounds of ore to 1 pound of coke and 1-3 of a pound of limestone. In the manufacture of the steel from which the rails are rolled, there are two fundamental processes; first, the reduction of the ore in the blast furnace; and then the conversion of the molten iron into steel in the converter. The description of the blast furnace which now follows will serve for all the subsequent branches of the steel industry which are treated in this number; for blast furnace practice is broadly the same to-day in every furnace throughout the country. Each fur-

MODERN BLAST FURNACE, IN WHICH THE ORE IS SMELTED, THE MOLTEN CAST IRON BEING TAPPED OFF AT THE BASE AND TAKEN TO THE CONVERTERS.

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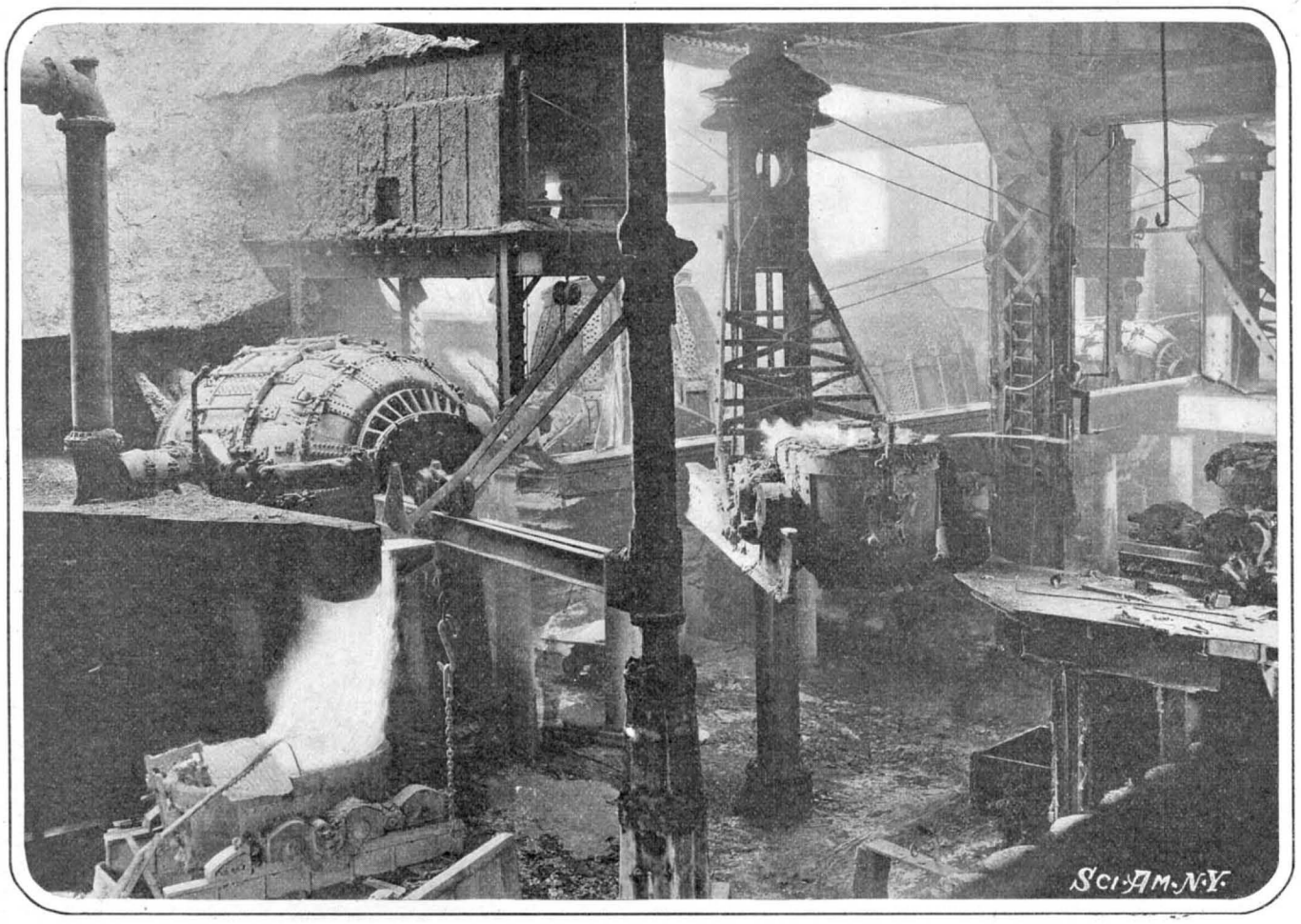
nace (there are eleven in all at the Edgar Thomson Works) consists, as will be seen in the accompanying engraving, of a huge steel shell varying from 75 to 90 feet in height. It has its largest diameter at about a quarter of its height, and tapers regularly to its smallest diameter at the top platform. The upper portion is known as the "stack," the lower portion as the "bosh," while below this is the "hearth," in which the molten cast iron collects. The bosh, which is just above the tuyeres, is provided with annular hollow bronze castings built into the brickwork, through which a stream of cold water is circulated for the purpose of keeping down the temperature of the brickwork at the hottest part of the furnace. It should be explained that the whole interior of the steel shell is lined with about three feet of brickwork.

In the early days of blast furnace practice, the hot gases were permitted to escape at the mouth of the furnace, but in later years the wastefulness of this practice was recognized, and the mouth of the furnace was closed by a massive cast-iron cup-and-cone arrangement, which is only opened for a fresh charge. In the latest designs there are two cones, one above the other, forming a chamber between them, on the principle of the air-lock, by which arrangement the escape of the gases is entirely prevented. The large steel pipe or flue which will be seen curving out at the right near the top of the furnace conducts the gases downwardly to a big drum or dust-collector, and from this the gas is led to what are known as the Cowper hot-blast stoves, to the left in the engraving, is a large cylindrical wrought-iron tower, about 20 feet in diameter and 80 feet in height. It is lined with firebrick and contains, on the side next the furnace, a large vertical flue, into which the furnace gases pass by way of a valve at the bottom. The rest of the interior of the stove is occupied by a mass of firebrick pierced with innumerable vertical flues extending from top to bottom. The hot gases from the blast furnace are ignited on entering the base of the large flue by admitting air to them by means of a valve, and the hot products pass up the main flue and down through the mass of brickwork, finally escaping to a lofty steel chimney. As soon as the firebrick "checkerwork," as it is called, with which the stove is filled, has been heated to the proper temperature, the gases are shut off and turned into the second stove. The cold blast from the blowing engines is now turned in at the bottom of the first stove, passes up through the heated firebrick and down through the main flue, and finally is led to the circular blast mains which surround the furnace just above the tuyeres. To supply the hot blast for a single pair of the largest furnaces of the Edgar Thomson Works requires a large amount of horse power, the engine house for each two furnaces containing five

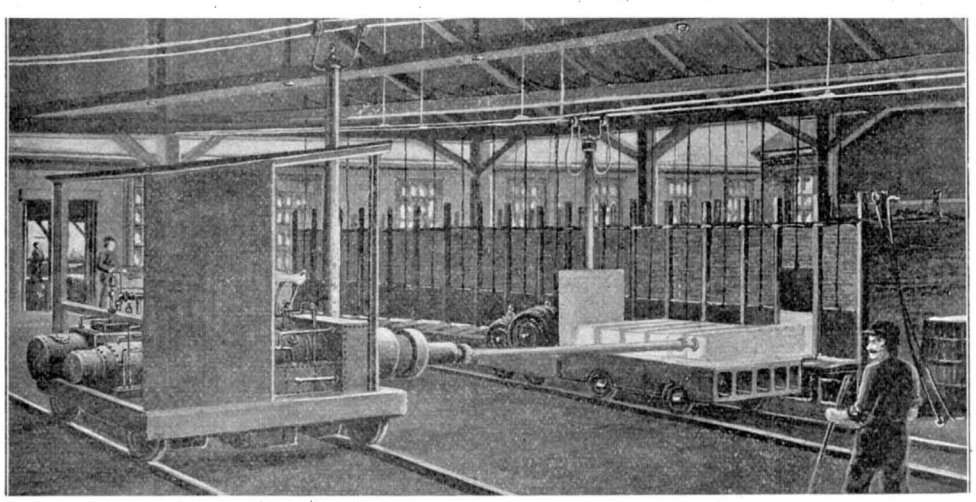


Group of four 15-ton converters, in which the molten cast iron is blown into steel at the rate of 3,000 tons per day.

THE LARGEST CONVERTER PLANT IN THE WORLD.

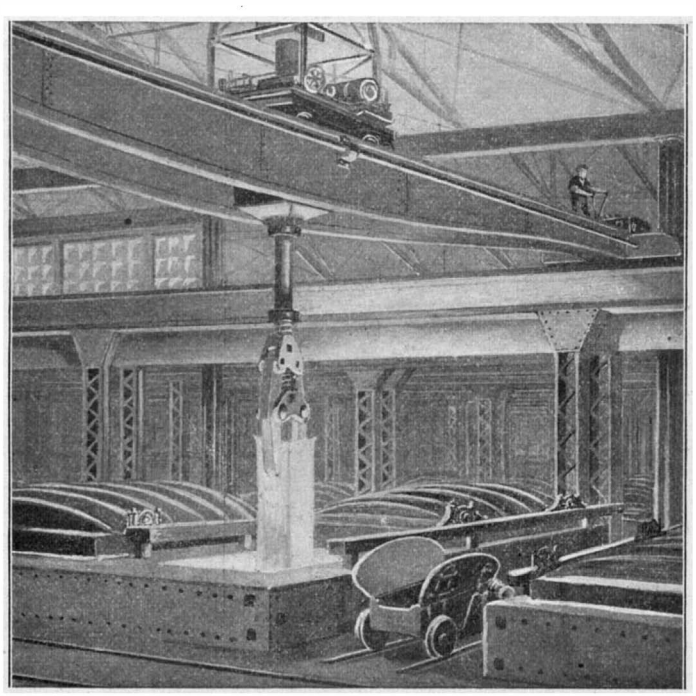
of which there are four to each blast furnace, with one in reserve. The charging of the blast furnace is accomplished by means of an inclined elevator with one or more steel buggies which travel from the ore pile and coke bins up to the furnace mouth, where their contents are automatically dumped.

The Cowper hot-blast stove, one of which is shown

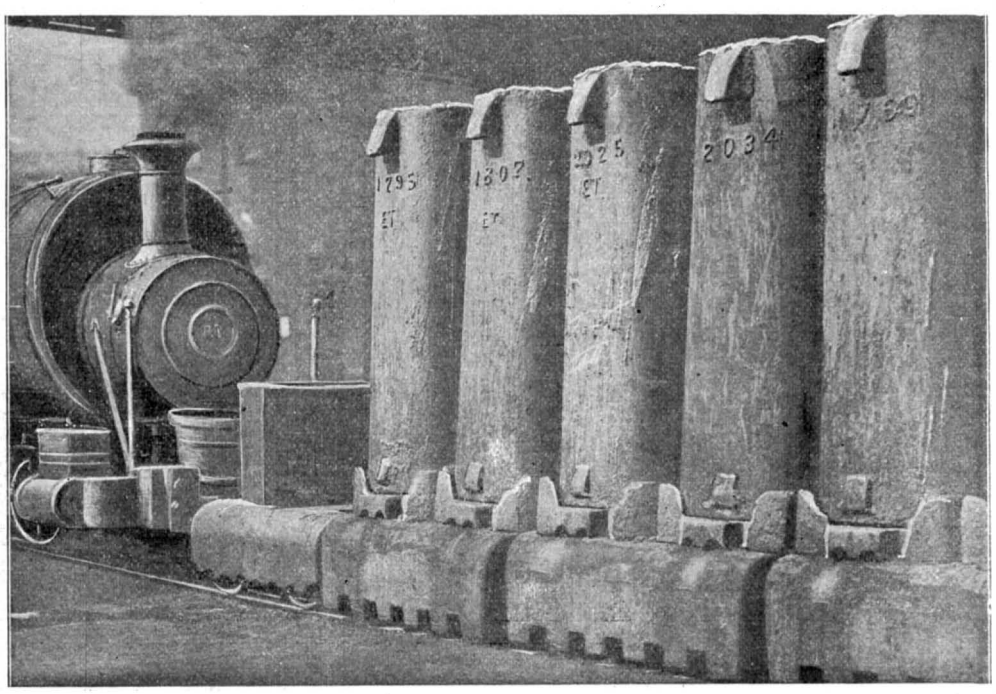


ELECTRO-PNEUMATIC CHARGER PUSHING BLOOMS INTO REHEATING FURNACES.

STOCK OF ROLLS FOR RAIL-ROLLING.



LIFTING HEATED INGOT FROM SOAKING PIT. INGOT CARRIED TO ROLLS IN ELECTRIC BUGGY IN FOREGROUND.



TRAIN OF INGOT MOLDS. AFTER CONVERTER TREATMENT THE METAL IS CAST IN THESE MOLDS.

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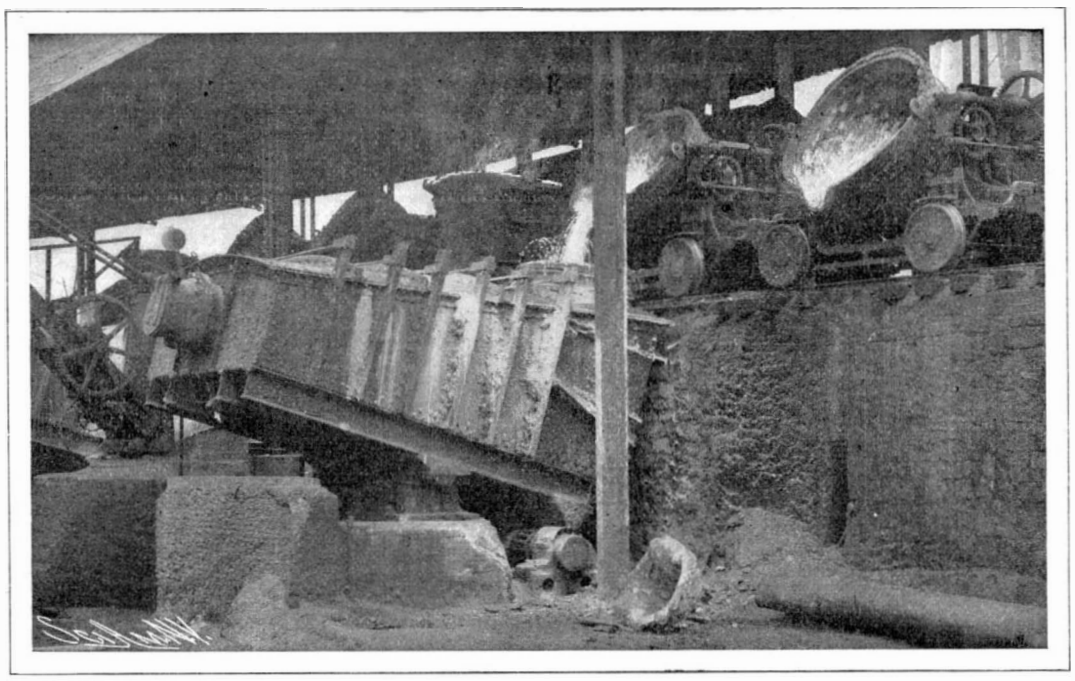
pairs of huge Allis-Chalmers blowing engines of 4,000 maximum horse power, capable of delivering each about 5,000 cubic feet of air per minute at 25 pounds pressure.

When once a blast furnace has been started, it is maintained day and night in continuous operation, the solids (ore, coke, and limestone) descending, and the gases rising to be carried off by the flue. The temperature ranges from about 500 deg. at the top of the furnace to 1,800 to 2,000 deg. at the base. If it were possible to break away one side of the furnace and examine the contents, we would find at the top of the furnace some eight or ten feet of raw materials at a temperature of about 500 deg. Below this would be a body of ore that was somewhat reduced. In the next lower portion, at a temperature of about 1,000 deg., the limestone would be found decomposed into lime and carbonic acid. Below this again would be a wider belt at about 1,600 deg. of temperature, where the iron, now reduced from the ore, would be combining with the carbon to form cast iron. Below this such oxides as silica and phosphoric acid would be produced, the silicon and phosphorus combining with the iron. Within the bosh the iron, and also the slag which results from the combination of the fluid with the various impurities, would be found to be completely melted, the molten mass finally collecting in the cylindrical hearth, the slag at the top, the heavier iron at the bottom.

From the time the charge is put in at the top of the furnace to the time of tapping the molten metal at the bottom is usually about twenty hours, and in the larger Edgar Thomson furnaces the casting takes place every three and a half to four hours, the amount of metal drawn off varying from 70 to as high as 120 tons at each cast. After the slag is run off, the hot metal is tapped into huge 17-ton ladles, which are drawn in trains of five or six to the metal mixers—large rectangular iron receptacles, each of a capacity of 175 tons, which are balanced, as shown in our illustration, on trunnions. The object of the metal mixer, which, by the way, is one of the important improvements in steel manufacture that have had their origin in the Edgar Thomson Works, is to reduce the casts that are brought from different furnaces at temperatures that vary considerably, to a common temperature and quality. The contents of the hot metal ladle are poured into the mixers at one end from a raised track, while other 17-ton ladles are continuously being filled from the opposite end of the mixer by swinging the latter over on its trunnions.

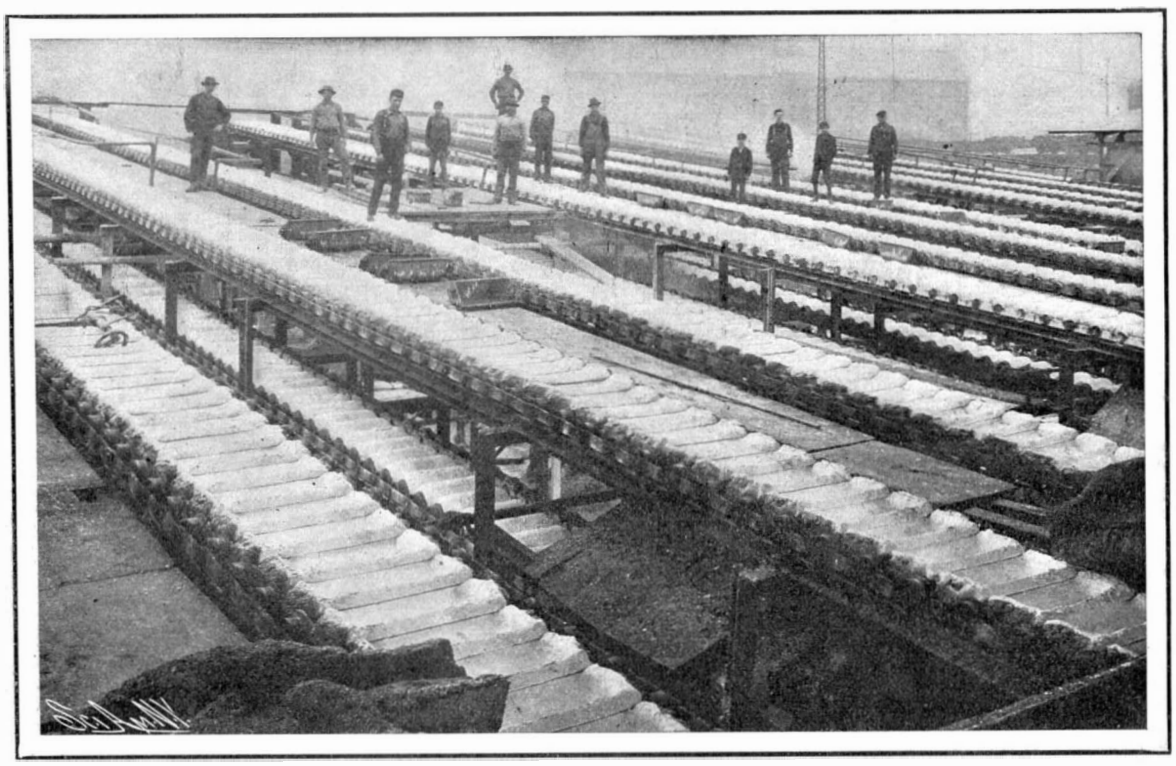
The metal is drawn in trains from the mixer to the converting mill, where it is "blown" in four 15-ton converters. We present a graphic illustration showing this wonderful plant (the largest in the world) at work, two of the converters being shown swung over to receive a 15-ton charge from the ladles, while two others are in the vertical position with the operation of blowing in full blast. The converter is a barrel-shaped, wrought-iron vessel, lined with refractory materials, and carried on trunnions, one of which serves to conduct the air blast to the bottom of the converter, which contains twenty air tuyeres, each of which is perforated with a number of ½-inch air holes. The blast of air from the blowing engines is started while the converter is in the horizontal position, and as soon as the charge of metal has been poured in. The converter is then swung to the vertical position, and the air is forced upward through the metal in from 150 to 200 separate streams. As the air rushes up through the molten mass, its oxygen combines with the carbon, silicon, manganese, etc., in the iron, and the violent combustion thus set up raises the temperature of the metal until it reaches the stage known as the boil. The process continues from 8 to 10 minutes, at the close of which time all the impurities and practically all of the carbon have been burned out, and only pure iron remains. The fierce combustion set up during this process raises the temperature of the metal from 1,800 deg. to as high as 3,200 or 3,300 deg. Among the many spectacular sights which render the operation of great steel works such as this of fascinating interest, there is none that compares with the blowing of steel in the converter. The agitation of the molten mass, as the air rushes through it, produces a dull reverberation, which mingles its deep note with the steady roar of the white-hot gases as they pour from the mouth of the converter. Every now and again heavy splashes of white-hot metal are thrown high in the air, and fall in a thick rain of brilliant coruscations to the ground. When the iron has been thoroughly purified, the blast is shut off and the charge is emptied into a 15-ton traveling ladle, and at the same time a certain amount of molten spiegeleisen is poured into the ladle with the iron, the proportion being such as to introduce into the metal the proper amount of carbon and manganese for the quality of steel rail that is to be made. A train of cast-iron ingot molds, with two ingots to the truck, is now drawn by a small engine beneath the pouring stand, and the hot metal is run into the molds through a nozzle in the base of the pouring ladle.

As soon as the ingot is set, the mold is drawn from it by a hydraulic stripper, and it is lifted by an overhead electric crane and lowered into a soaking pit or heating furnace, where it is heated to the proper temperature for rolling. From the soaking pit it is taken to the mill and given seven passes through the blooming rolls, by which it is reduced to a section 9¼ inches square and 15



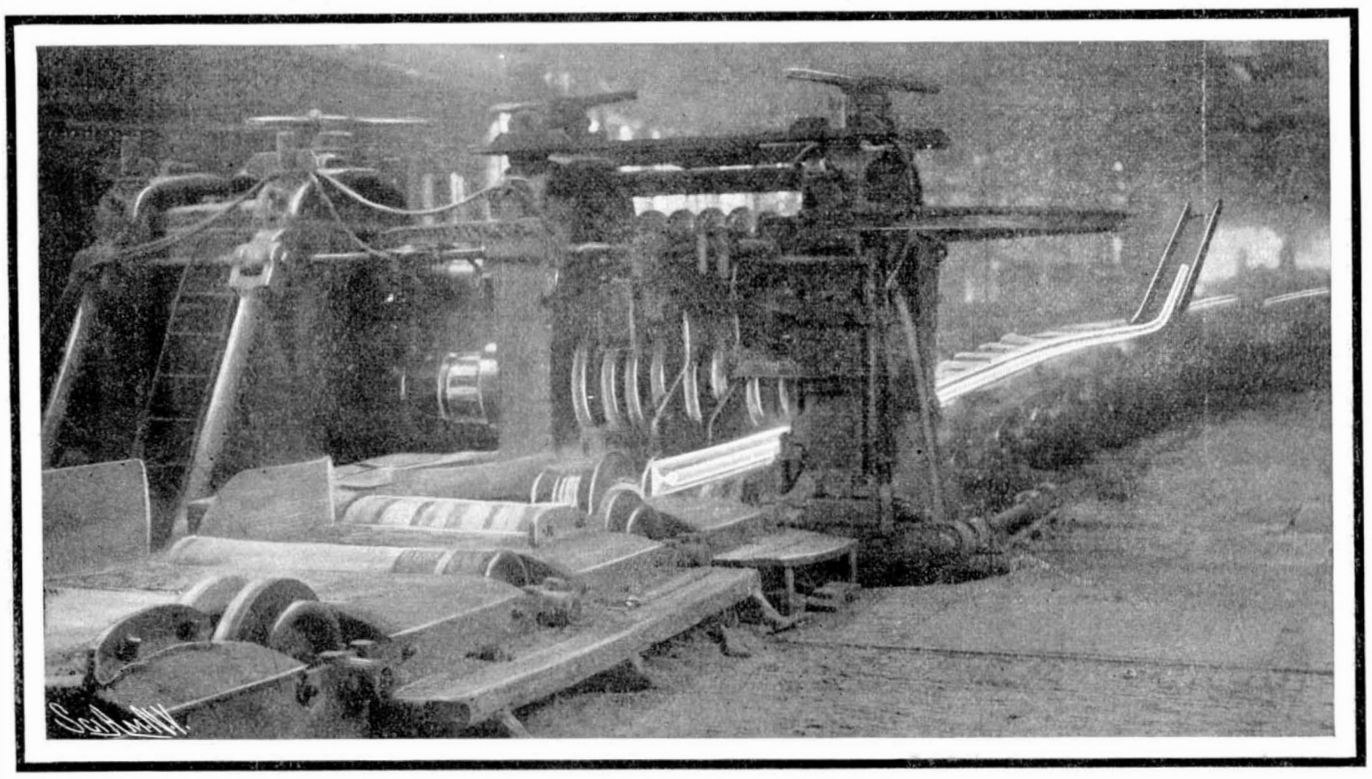
The molten cast iron from the blast furnaces is brought in ladles to two 150-ton iron receptacles and mixed, to bring the metal to an even temperature for treatment in the converters.

THE 150-TON METAL MIXERS.



The chain of molds passes continuously beneath the ladle, each mold receiving its quota of the hot metal.

STRAIGHT-LINE PIG-CASTING MACHINE.



The rails are rolled down from the billet in three successive sets of rolls (roughing, intermediate, and finishing), and the process is continuous down a mill that is 900 feet in length. The output of this mill is 3,000 tons or 7,000 rails per day.

INTERMEDIATE ROLLS IN THE RAIL MILL.

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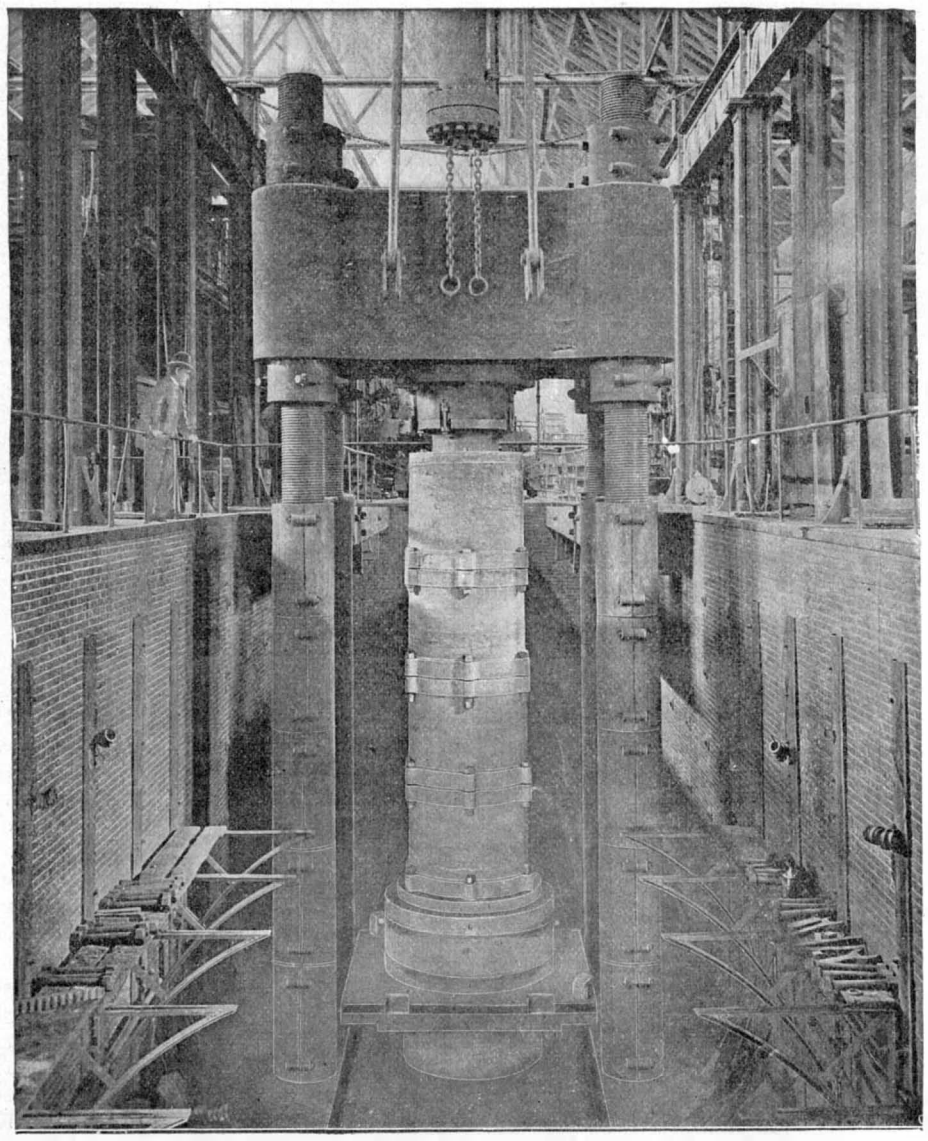
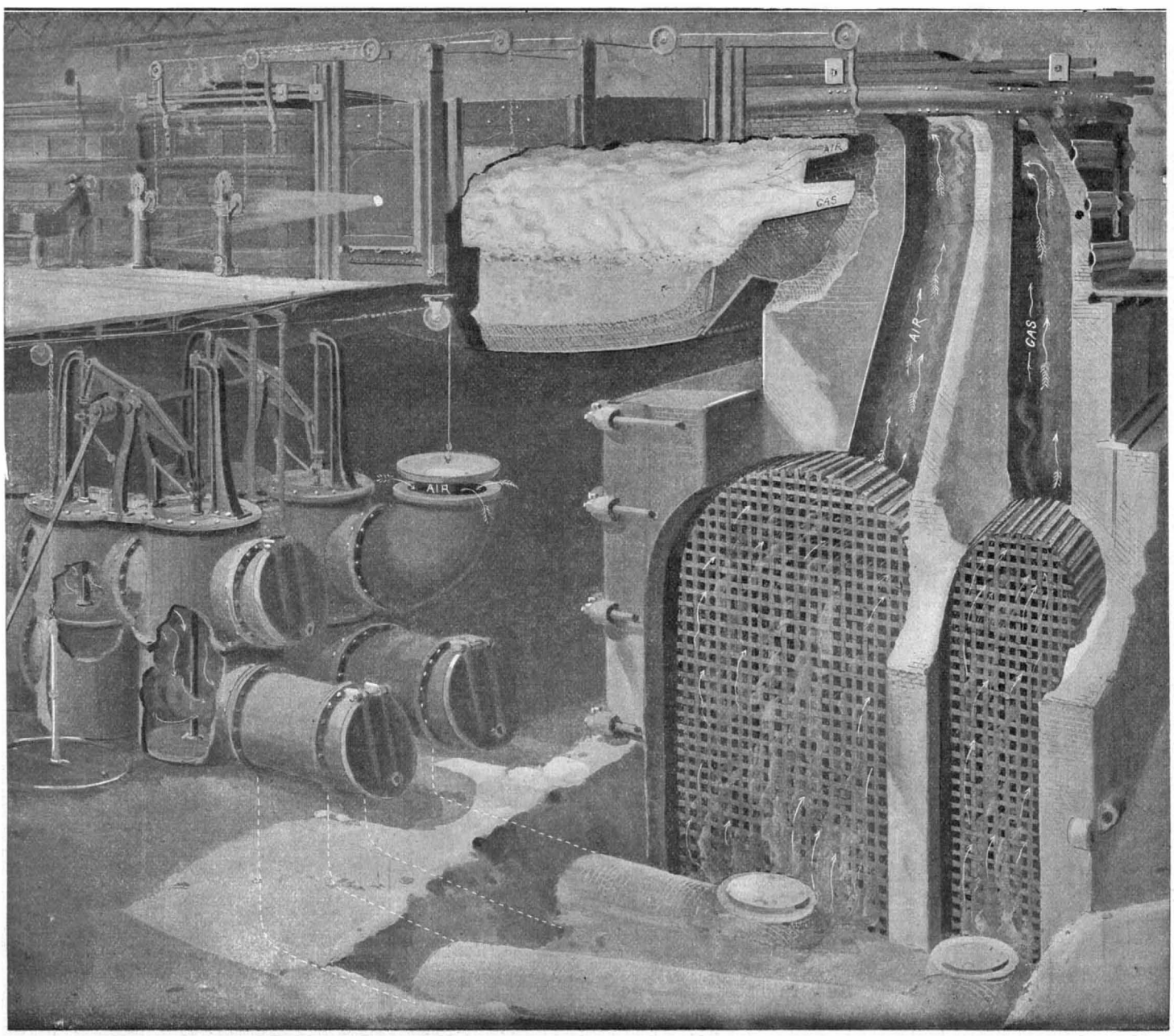
feet in length. Then it is sheared into two or three lengths, according to the length of the rail which is to be rolled. The blooms, as they are called, are now heated in the bloom furnaces and carried direct to the great rail mill, consisting successively of roughing rolls, intermediate rolls, and finishing rolls, which extend one after the other down the full length of a building that is 900 feet in length. In the roughing rolls the bloom receives five passes, during which it is brought down roughly to the desired section of rail. It then, without any reheating, passes on to the intermediate or "short" rolls, where it receives another five passes and is brought still more closely to its finished shape. At this point is introduced at these works a most important innovation in rail rolling, known as the Kennedy-Morrison rail-finishing process, to describe which it is necessary to go back in history a little, and explain that a few years ago it was customary to let the rail pass through the three sets of rolls and be finished on a single heat without any intermission in the process. This gave good results when rails were lighter, but as the section of the rails increased in later years, the greater mass of steel in the rail caused it to retain its heat longer, and it passed through the finishing rolls at too high a temperature for good results. Consequently, the modern 80 to 100-pound rail had not been giving such good results as the earlier 50 to 70-pound rail. To overcome this difficulty, the rails, after passing through the short rolls, are left to cool on a table for from 45 to 90 seconds, at the end of which time they are passed through the finishing rolls. Rolling at a lower temperature has produced a much better quality of metal, particularly in the head of the rail. After leaving the finishing rolls, the rails are sawn into lengths of 30 or 60 feet as the case may be. They are then passed through the cambering rolls, where they receive sufficient camber to insure that when the rail is cooled, it will be practically true and straight. After they have cooled off upon the hot beds, the rails pass to the straighteners, then to the chippers and filers, and finally to the stock yards, where they are loaded on to the cars at the rate of between 7,000 and 8,000 rails, or say 3,000 tons of finished steel, per day.

In closing our account of this wonderful industry, emphasis should be laid upon the fact that the work of smelting the iron in the blast furnace is continuous day and night, year in, year out, absolutely without intermission. The converters, however, and the rolling mills are shut down from Saturday at 1:30 o'clock in the afternoon to 5 o'clock on Sunday evening. During this interval the product of the blast furnaces, instead of being poured into the mixers, is run into the pig-casting machine. This consists of a series of parallel endless chains of molds which pass in front of the pouring mouth of the ladle. Each mold receives its quantity of metal at the lower end of the chain, and delivers the cast pig iron at the upper end of the system, where it is dumped into railroad cars for shipment.



OPEN-HEARTH CASTING PIT, SHOWING THE FLUID-COMPRESSION PLANT.



SECTIONAL VIEW THROUGH OPEN-HEARTH FURNACE, SHOWING REGULATING VALVES, CHECKER-WORK AND FLUES.

MANUFACTURE OF GUN STEEL AND ARMOR PLATE.

Too much cannot be said in praise of the policy of the government in its encouragement of the construction of navy and army material by private firms that are capable of undertaking this class of work. The more perfect and extensive the plants, the more experienced the working staff of the establishments that manufacture gun steel and armor plate, the more speedy will be the completion of contracts and the greater the reserve forces of the nation, should it ever be called upon to face the crisis of a sudden war. There is no branch of the manufacture of war material that calls for more thorough scientific knowledge, a wider range of experience, and more highly developed mechanical appliances, than that of the production of Krupp steel for the armor and fluid-compressed steel for the guns of our modern warships. By the courtesy of the Bethlehem Steel Company, we are enabled to present a series of views of what is recognized as the most important gun and armor plant in this country.

In the whole range of the iron and steel industry there is no single branch, not even that of railmaking, that calls for plant and machinery of such colossal size as this; and though the total output measured in mere dead weight does not compare with that of the industry which has been described in the preceding article, it must be remembered that whereas steel rails may cost anywhere from $20 to $40 a ton, a finished gun is worth $1,000 per ton, and finished armor plate from $400 to $500 per ton. Nowhere among the plants that manufacture iron and steel in bulk can we find an instance where the elements of time and labor enter so largely into the cost of the finished product.

THE OPEN-HEARTH PROCESS.—Broadly speaking, it may be said that the bulk of the steel that is annually produced throughout the world to-day, with the exception of a relatively insignificant amount, is made either by the Bessemer or the open-hearth process. The former process was described in the preceding article, and every ton of finished rail that goes out of the Edgar Thomson Works is made by the Bessemer process. At the Bethlehem establishment, however, no Bessemer steel whatever is manufactured, the whole of it being made by the open-hearth process. The conversion of the cast iron into steel by the Bessemer process is accomplished, as we have seen, in from 10 to 15 minutes, and it is the simplicity and rapidity of the process that has so greatly cheapened the cost of steel throughout the world. But while Bessemer steel is well suited for steel rails and for a large variety of

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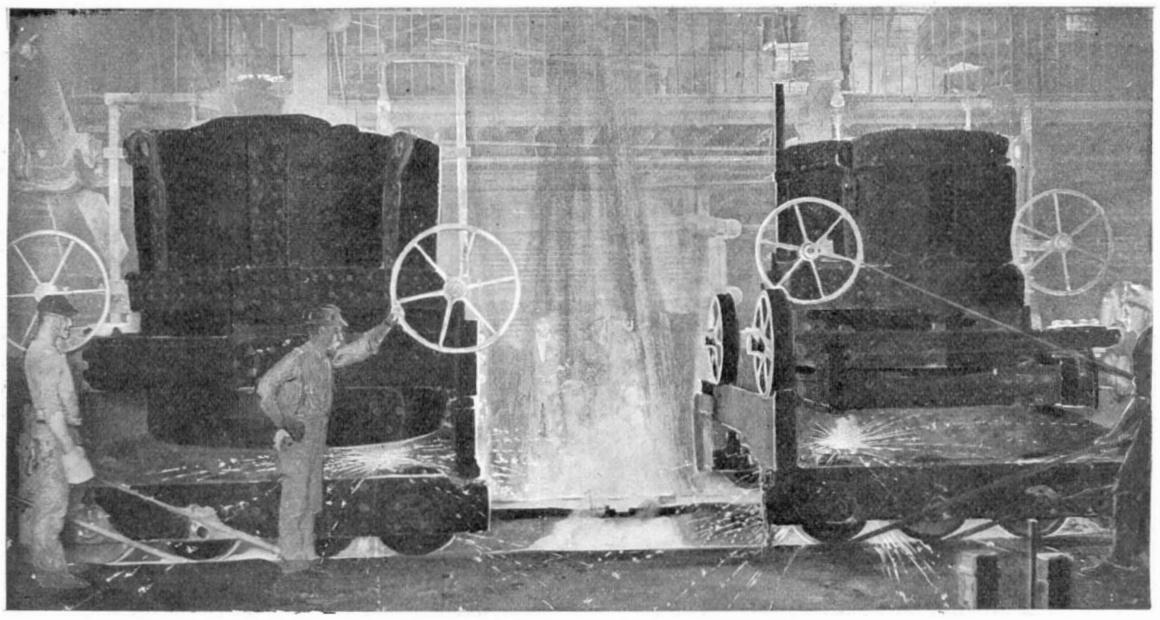
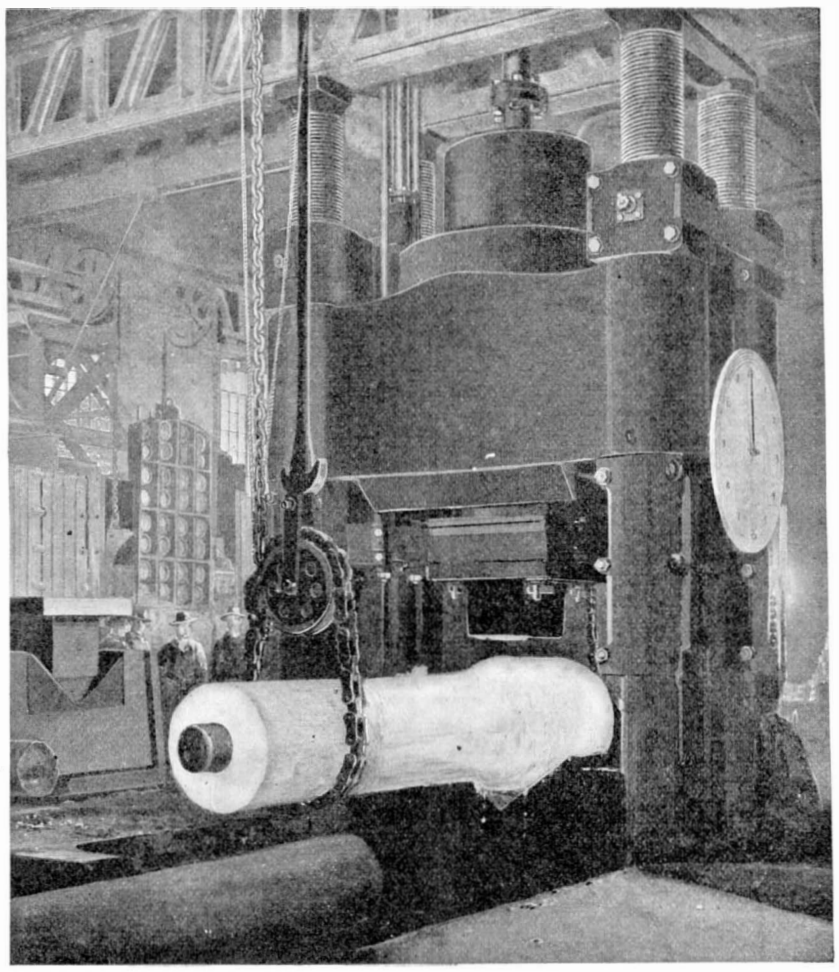
structural material, it is not possible to secure by this rapid process the high qualities which are demanded in all specifications for gun steel and armor plate; and it is only by the slower and more carefully watched and manipulated open-hearth process that these qualities can be imparted. The superior results obtained with the open-hearth process are due to the fact that the process of decarbonizing the cast iron being greatly protracted, it is possible to make a larger number of successive tests, and turn off the heat at the moment when the steel in the furnace has reached the exact composition required. In the Bessemer process the impurities and the whole of the carbon are burnt out of the hot metal in a few minutes, and the proper percentage of carbon is sought to be secured by adding some spiegeleisen as the blown metal is being poured into the ladle. The open-hearth process, however, occupies from eight to twelve hours for each heat, and the operator can tell at any time just what is the chemical condition of the heat, and can control with the greatest nicety the temperature.

The high qualities of gun steel and armor plate are secured by varying the composition of the furnace mixture; by the method of treatment in the furnace; and by subsequent treatment of the metal by fluid compression, forging, tempering, and annealing. Gun steel must be hard, to resist the friction of the projectiles and erosion of the powder gases; elastic, so that it may give under powder pressure and yet return without permanent set to its original dimensions; and it must have a high ultimate breaking strength. The desirable qualities for armor plate are extreme hardness at the face combined with great toughness throughout the whole body of the plate. In Harveyized armor this toughness is secured by the introduction of a certain amount of nickel, and in Krupp armor of chromium and other elements during the furnace treatment. The desired physical qualities are further developed by that elaborate system of forging, tempering, and annealing, which renders the manufacture of armor plate so tedious and costly.

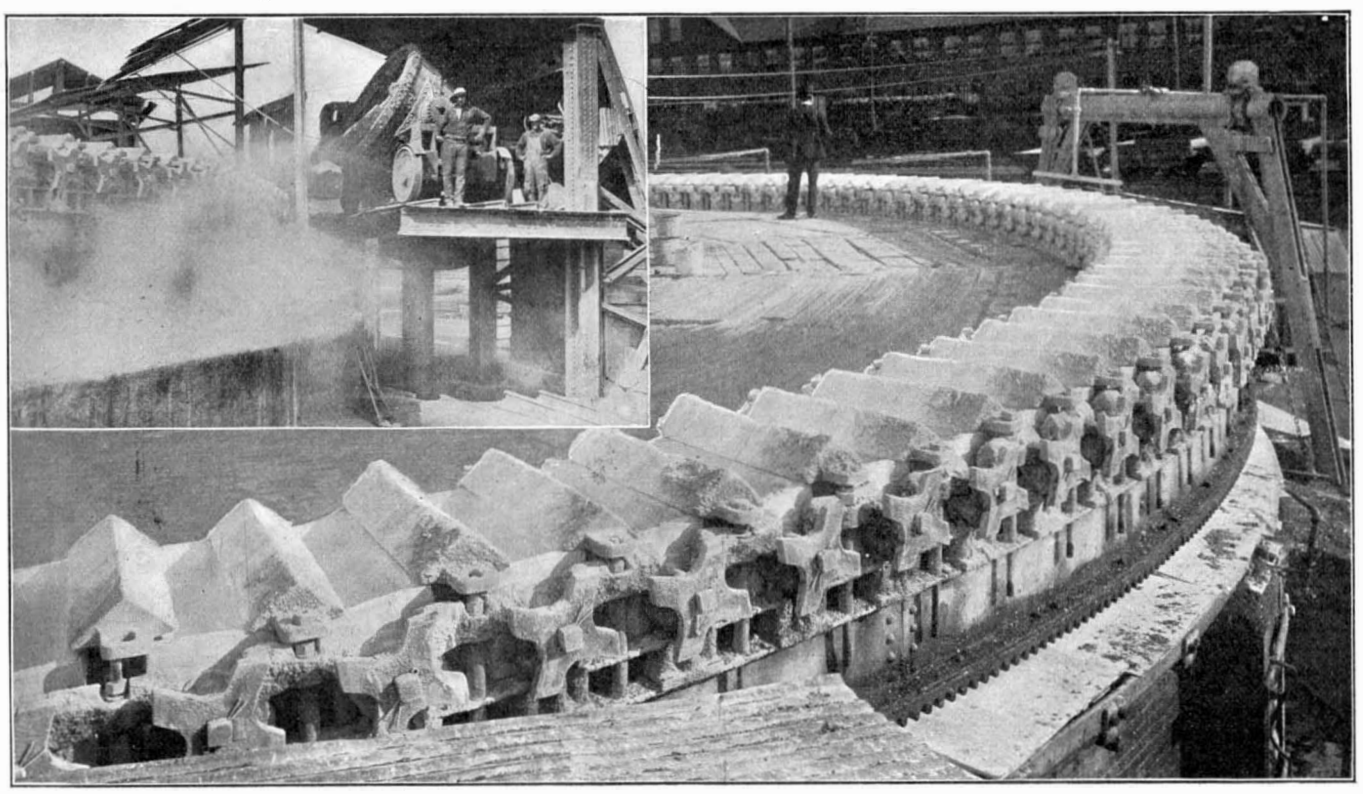
The open-hearth furnace is a large dish-shaped structure lined with refractory brick and sand, into which the mixture is loaded by powerful Wellman-Seaver electric charging machines, that run on tracks laid upon the charging platform in front of the furnaces. The furnace is heated by producer gas, which is fed through the large regulating valves shown in our engraving below the charging platform. From the valves the gas passes through a mass of firebrick checker-work (whose function is the same as that of the hot-blast stove used in blast-furnace practice), and from the checker-work it enters the furnace through the lower flue shown in the engraving. Air is admitted to the furnace by way of the valves, and passing through another mass of checker-work built alongside the first mass, finally enters the furnace by two flues, one on each side of the gas flue. Combustion takes place at once, at a temperature ranging from 2,700 to 3,000 degrees. The products of combustion pass over the charge, out at the opposite side of the furnace, and down through a duplicate set of flues and checker-work, exactly similar to those through which the gas and air entered, thereby raising the checkerwork to a very high temperature. About every twenty minutes the valves are thrown over, and the flow of the gases is reversed. By this regenerative process the gas and air enter the furnace at a temperature of from 1,500 to 1,800 degrees. As soon as the various impurities have been burned out of the charge, and the percentage of carbon, etc., brought down to the desired ratio, the furnace is tapped at the rear, and the steel is run off into the molds. One of our engravings shows a large ingot weighing 62 tons that has been cast to form a side armor plate for the new battleship "Virginia." The large mass at the top of the plate contains an excess of metal known as the "sinking head." This is formed in the mold with the purpose of increasing somewhat the density of the metal and closing any cavities which might form during cooling in the casting.



CASTING AN ARMOR-PLATE INGOT.



HOLLOW-FORGING A GUN TUBE IN THE 5,000-TON PRESS.



CIRCULAR PIG-CASTING MACHINE.

Fluid Compressor.—The metal which is to be worked up as gun steel is subjected to fluid compression, which is designed to remove certain defects that are common to all steel ingots not so treated. These defects are the formation of blow-holes, "piping," which is the formation of a hollow cavity through the center of the ingot in cooling, and segregation, which is the mechanical and chemical separation of the component parts of the solidifying steel, due to the fact that each of them has its own temperature of cooling. Now, by subjecting the molten metal during the cooling to an extremely high pressure, the above-mentioned defects are prevented, or at least very largely mitigated. The 7,000-ton press, as herewith illustrated, is of monumental proportions. It consists of an upper head weighing 120 tons, which carries the plunger, a 135-ton base, containing the hydraulic cylinder, and four vertical connecting columns, each 50 feet long and 19 inches in diameter. After the molten metal has been poured into the mold, which is built up in sections, the mold is raised under a pressure of 7,000 tons, and a plunger attached to the head bears down upon the fluid metal, preventing its escape and compressing it. When the ingot has cooled, the ends are cut off in a lathe, and an axial hole is bored through its center. It is then placed in the furnace, and being hollow, heating takes place very evenly throughout the whole mass, and the danger of cracking is removed. The ingot is removed from the furnace at a temperature of about 1,900 degrees, a steel mandrel is passed through its center, and it is placed under the hydraulic forging press. The mandrel serves as an internal anvil, and the work of the press is concentrated upon less than half of the thickness of metal that it would act upon if the piece were solid throughout. Thus the metal receives that thorough "working" which is the very soul of first-class forging. All armor plate and gun forging is done at the Bethlehem Works under hydraulic presses, of which there are three—one of 2,500 tons, another of 5,000 tons, and a huge affair of 14,000 tons, the first two being used for gun forgings, while the biggest

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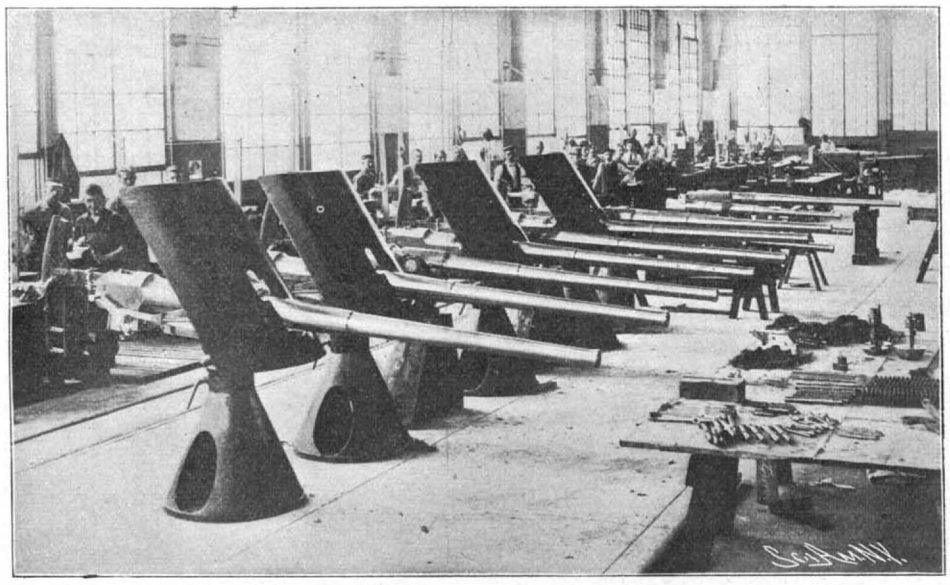
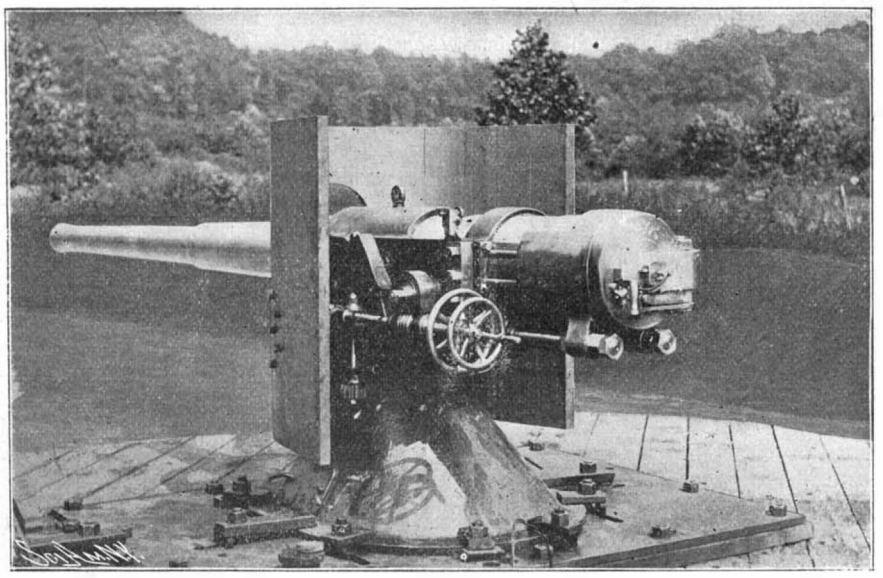
press, a truly gigantic structure, is mostly engaged in the manufacture of great masses of armor plate.

THE HYDRAULIC FORGING PRESS.—The general construction of the hydraulic press is similar to that above described of the fluid compressor. The hydraulic cylinders are carried in the upper head, and the travel of the piston is controlled by a hydraulic lever in the hands of an attendant. A disk and pointer attached to the side of the press indicate the number of inches of stroke of the piston, and as the same length of stroke is maintained throughout a complete revolution of the forging in the press, the piece is roughed out with an accuracy as to diameter and line that greatly reduces subsequent work in the machine shop.

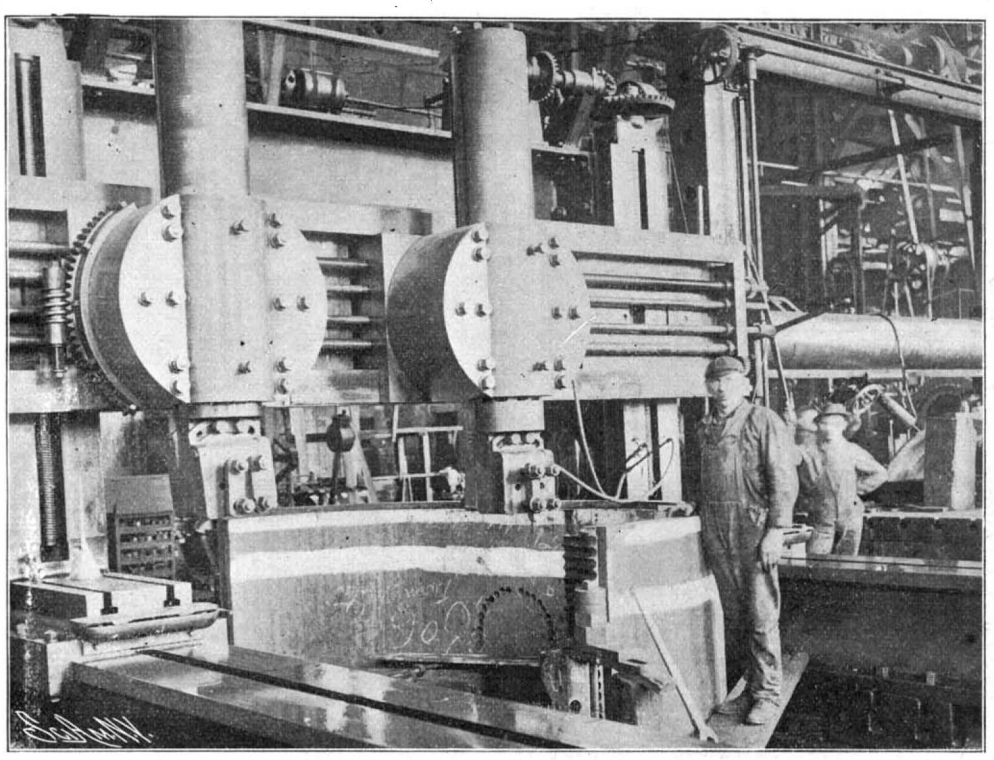
ANNEALING.—The successive heating and forging that are necessary in the production of such large pieces set up in the work a complication of forging strains which are relieved by treatment in the annealing furnace. In this process the forging is slowly and carefully heated to a temperature slightly above the point at which crystallization is destroyed and the molecules thrown into an amorphous condition, and it is then allowed to cool very slowly. During the cooling the molecules rearrange themselves, leaving the metal in a state of complete rest. After annealing, the forgings are oil-tempered to impart the necessary toughness. This is done by lowering the piece into a large cylindrical furnace, whence it is lifted at a predetermined temperature and lowered suddenly into a bath of cold oil. As the temperature of the piece is slightly above the recalescent point, there is no time during the cooling process for the formation of crystals, and the result of the readjustment of the molecules which takes place is to give that high elastic limit and ultimate tensile strength that characterize gun steel. The forgings are again annealed to relieve the metal of any hardening due to the cooling process, and they are then taken to the machine shop, where they are bored, turned, and assembled or built up into the finished gun. A chapter could be written on this interesting department; but we must be content to refer to the accompanying views of some of the latest finished guns, and direct the reader's attention to the chapter by John F. Meigs, the ordnance expert of the Bethlehem Steel Works, at the commencement of this issue.



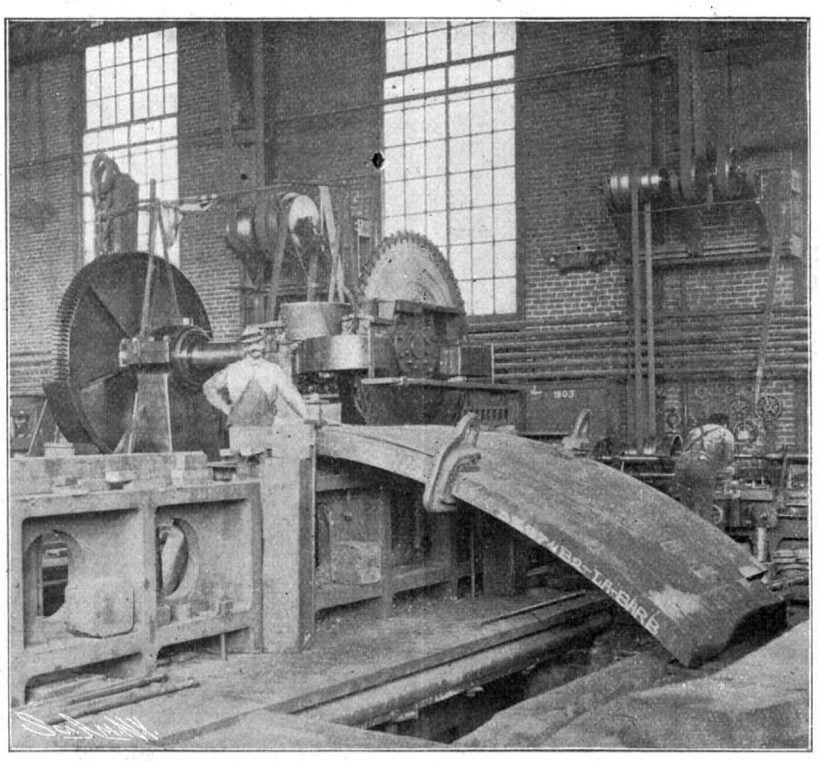
GROUP OF 6, 3 AND 1 POUNDER GUNS IN GUN SHOP.



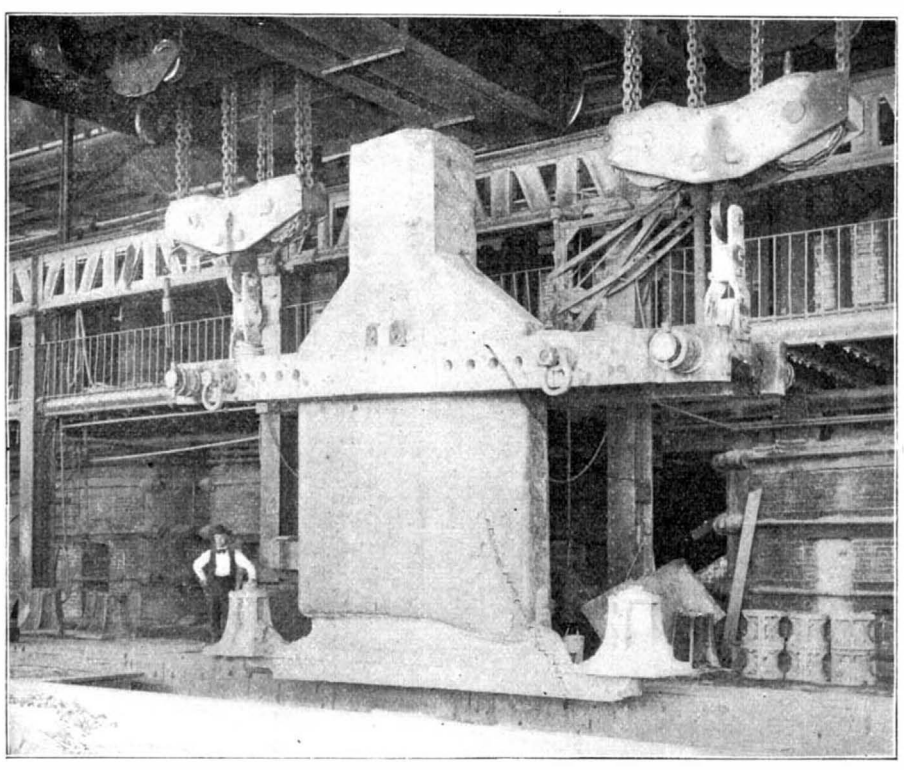
FOUR-INCH, 50-CALIBER GUN AT PROVING GROUND.



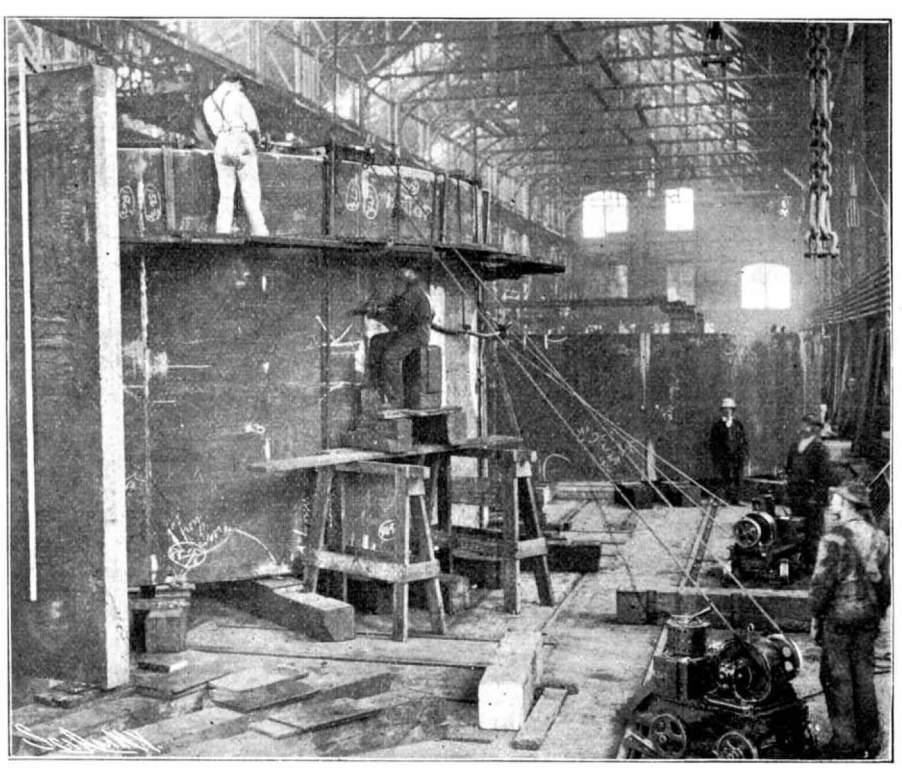
PLANING RABBET IN "LOUISIANA'S" CONNING TOWER.



SAWING ROUGH ENDS FROM A "LOUISIANA" BARBETTE PLATE.



LIFTING FROM THE CASTING PIT A 62-TON INGOT FOR SIDE ARMOR OF BATTLESHIP "VIRGINIA;" PART OF MOLD STILL ATTACHED AT BASE.



ERECTING BARBETTES OF THE BATTLESHIP "LOUISIANA;" GRINDING DOWN ROUGH EDGES AT THE JOINTS.

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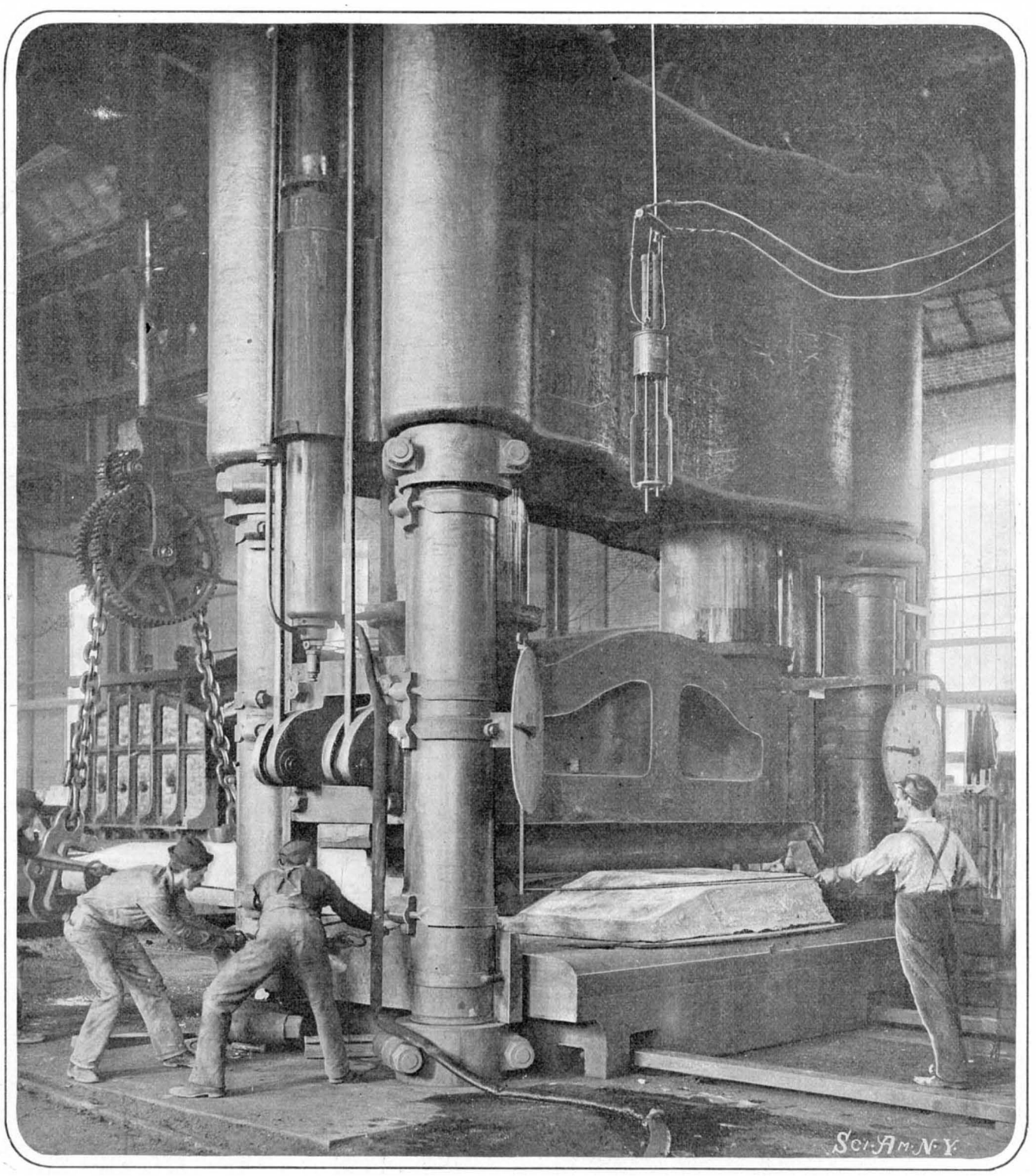
MANUFACTURE OF ARMOR PLATE.—As already explained, the armor-plate ingots are cast with a large excess of metal, which serves both as a "sinking head" and also as a rude sort of handle, by which the enormous mass may be manipulated on the mandrel of the hydraulic press and transferred to and from the furnace. The excess of metal in an armor-plate ingot is greater than that of any other mass of metal casting, the finished plate representing on an average about 40 per cent only of the original casting. Some of these castings weigh as high as 275,000 pounds. When the ingot has been hauled to the forge, its "sinking head" is placed in one end of a massive cast-steel sleeve, from the other end of which projects a long steel bar about two feet in diameter, which is provided with sliding balance weights. The sleeve is supported in an endless chain sling from an overhead crane, by which it is transferred from the heating furnace to the hydraulic press. Here the total "squeeze" given to the plate when it is upon the anvil is the same as though a big battleship like the "Maine" were permitted to bear with its full weight upon it. The massive forging is lifted, turned over, flattened (kneaded as it were) and brought down to size with an ease which must be seen to be appreciated. At the first forging the ingot is roughed down to the approximate shape of the finished armor plate, but is considerably thicker. It is now ready for that most important process of hardening the face, technically known as cementation. This varies greatly in its details for Harvey and for Krupp armor, although its general principles are the same. In both processes the plate is placed in a furnace, and exposed for from three to four weeks to the action of highly carbonaceous material. In the case of the Harvey plate the carbonizing is effected by a layer of bone dust, charcoal, and other suitable materials. In the Krupp process the carbonizing agent is used in the form of a gas. After the plate has taken up an excess of carbon for the depth of an inch and a quarter to an inch and a half, it is returned to the forge, heated, and forged down to the finished thickness. Then it is transferred to the machine shop, where test specimens are removed and subjected to tensile tests in the presence of naval inspectors. Here the plate is sawn down to the correct size, and such machining as is necessary is done upon it. We present some illustrations of the remarkable collection of machinery in the armor-plate machine shop. It was all built specially for this work, and is framed on a colossal scale. In one place will be seen a circular saw that is capable of taking a cut through a steel plate 24 inches in thickness and 33 feet long. Elsewhere will be seen a huge rotary planer engaged in taking a 6-inch cut from the edge of a 10-inch plate faster than a saw will cut on a 6-inch strip from the same plate. Practically the whole of the machine work has to be done before the final hardening of the armor-plate by the water spray, for the steel tool does not exist that can touch the hardened face of a Harvey or Krupp plate. The plate then takes a journey to the forge again, where it is carefully straightened or bent, as the case may be, and brought to the desired form. Time and again the huge mass, weighing as much as a locomotive, will be lifted on to cars and transported from one building to another, undergoing operation after operation, until at last it is ready for the process of hardening, which consists of heating the plate to a temperature slightly above the recalescent point, and then case-spraying it with innumerable streams of water delivered under high pressure. Then follows the oil-tempering, to remove strains, and another heating for the final "rectification" to the proper shape. After the hardening, the plate is again taken to the machine shop, where additional tests are taken for the satisfaction of the navy inspectors, and it receives its finished machining by means of grinding machines. In the rough-machining already alluded to, the plate was brought practically to its finished shape and size, and now that its face has been hardened, it is only possible to act upon the inch and a half of extremely hard surface by means of the emery grinders. All the warped surfaces, such as those at the portholes, at the sighting hoods, etc., have to be chipped and finished by hand with files, the outer hardened portion being ground down. Then follows the drilling of the holes for the bolts by which the armor is fastened to the backing and framework of the ship, and the tapping of the bolt holes, after which the armor plates are assembled to make sure that the joints are true and close. One of our illustrations shows the barbettes for the battleship "Louisiana" in the erecting shop, and the workmen busy with the grinding wheels, finishing off the top edges and smoothing down irregularities in the vertical joints. Each grinder is operated by a rope drive from a portable motor standing on the floor of the shop. After the armor has been assembled and the bolts tried in the bolt holes, it is inspected carefully by government representatives. Then it is taken down, the bolt holes are filled with tallow and white lead, and the plates stamped with the name of the vessel and the part of the ship to which plate is assigned. The final operation is the weighing, which, in the case of such costly material, is carried out with the greatest care.



STRAIGHTENING A 14-INCH ARMOR PLATE UNDER A HYDRAULIC PRESS.

WHY ARMOR PLATE IS COSTLY.—The general public has always been mystified at the extremely high price paid for armor plate. We have endeavored to indicate in the course of this article some of the causes of this high cost, the most important of which is the great length of time required for the successful manufacture of a plate; for, on an average, every plate is being constantly worked upon, either in furnace, forge, machine shop, or annealing and tempering department, for a continuous period of nine months. Other causes of high cost are: the large number of separate operations, the frequency with which the great masses must be transported, and the distances over which they must be carried in their journey from one department to another. To illustrate the vast scale on which the works are laid out and the distances to be covered from shop to shop, we may mention that the whole establishment extends in one direction continuously for a length of a mile and a quarter, and that the forty or fifty handlings and transshipments, which occur in making a single Krupp plate, take place in and between such buildings as the open-hearth structure, which is 111 feet wide by 1,950 feet in length; the machine shop, 116½ feet in width by 1,375 feet in length; the armor forge, 850 feet in length; and a face hardening department and an armor-plate machine shop, both of which are but little less in size. Further elements of expense are the large percentage of losses which is liable to occur, the high first cost of the extensive plants that must be laid down, and the fact that new and improved methods of manufacture may at any time render the plant more or less obsolete. The greater cost of the Krupp armor is largely compensated for by its much greater resisting qualities, which make it possible to give equal defensive qualities for 20 to 25 per cent less weight of armor.

STATISTICS OF OUR IRON AND STEEL PRODUCTION.

The statement that last year forty per cent of the pig iron in the world was produced in the United States gives one no very definite realization of the quantity of that product, though he be reminded on every hand by iron and steel ships, bridges, railroads, buildings, machinery, tools, nails, tacks, etc., *ad nauseam*, that this is the iron age. Even the statement that the United States last year mined over thirty million long tons of iron ore, gives one no adequate impression of the vastness of this amount. On the other hand, if one should see the entire iron ore production of the year piled up in a single heap, he would readily comprehend this quantity by a comparison of the pile with familiar objects in the landscape. This shows us that it is large numbers instead of large quantities which confuse the mind; for example, the statement that a wagon holds over 30,000,000 grains of coal would give a person a very hazy idea of the actual quantity specified, but he would immediately comprehend the quantity if told that it represented two tons; for a larger unit of weight would be used, thereby reducing the count to a figure well within the mental grasp. Thus in trying to represent to our readers just how large are the quantities of materials used in the iron and steel industry, we have endeavored to choose larger units of measurement; and finding that our standard measures

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are far too small for the purpose, we have resorted to the use of familiar landmarks as bases of comparison.

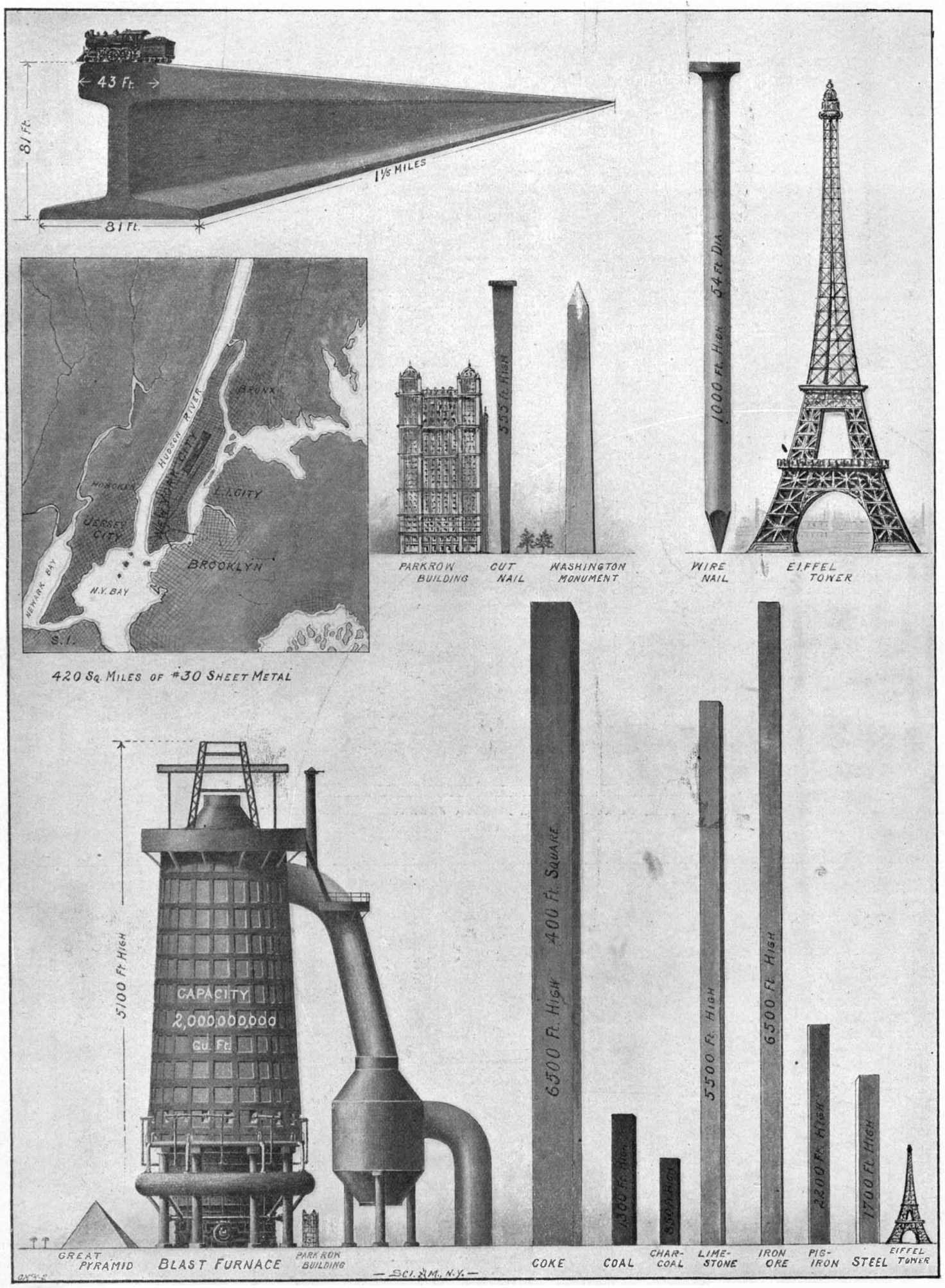
As a unit of bulk, no larger single monument has man produced than the old pyramid of Cheops, and large though it be, it is all too small when used as a unit by which to measure the stupendous volume of material used in our pig-iron production of a single year. In the accompanying illustration, the huge blast furnace shown at the left represents a furnace which would receive at a single charge all our iron ore production during the year 1902, together with the fuel and limestone used. The charge measures approximately two billion cubic feet, or to use our proposed unit of bulk, this would be equivalent to twenty-four pyramids. As many individuals may have formed no adequate conception of the size of the Great Pyramid, we have used as an additional basis of comparison the tallest building in the world, namely, the Park Row Building in New York. This building measures 390 feet in height, and it would require thirteen such buildings, placed one above the other, to equal the height of our hypothetical blast furnace.

FUEL.

Of the contents of the blast furnace, by far the larger bulk is fuel, though the weight of the iron ore is almost twice that of the fuel. The square columns in our illustration will serve to give one some idea of the amount of fuel consumed last year by the blast furnaces of the United States. No exact figures are available for 1902, but a fair estimate would be about 16,000,000 tons of coke, 1,600,000 tons of coal, and 300,000 tons of charcoal. Coke is so light that if the 16,000,000 tons were built up in a column 400 feet square, the column would reach an altitude of 6,500 feet. No human monument is large enough to give us, by comparison with this column, any idea of such a height. If the base of the column were situated at sea level, a person at the top could look down on the summit of Mount Washington, N. H., and it would overtop every mountain in this country east of the Rockies.

Our column of coal includes both anthracite and bituminous. In the last two years there has been a considerable falling off in the use of anthracite while bituminous coal mixed with coke has shown a great increase over former years, so that our column would probably be made up of two parts bituminous to one anthracite coal. Their combined bulk would form a column 200 feet square by 1,300 feet high—a midget in comparison to the coke column, but not so small after all when compared with the Park Row Building.

Charcoal, which is the smallest item in the fuel statistics for 1902, or about one-fifth of the number of tons of coal, yet forms a column nearly two-thirds the height of the coal column, or twice that of the Park Row Building.



COMPARATIVE DIAGRAM SHOWING THE TOTAL ANNUAL AMOUNT OF RAW AND FINISHED MATERIALS OF THE IRON AND STEEL INDUSTRY IN THE UNITED STATES.

FLUX.

The amount of limestone used for fluxing purposes last year amounted to 9,490,090 tons. This would make a column 5,500 feet high, with a cross section 200 feet square. It may be interesting to note here that oyster shells are used in one of the furnaces in Maryland in place of limestone.

IRON ORE.

The next column, which is of a height equal to that of the coke column is composed of 34,636,121 tons of iron ore. However, this represents in bulk only one-quarter that of the coke.

PIG IRON.

All the above-mentioned materials were used last year to produce 17,821,307 tons of pig iron. This makes a column twice the height of the Eiffel Tower, the tallest monument to human skill in the world.

STEEL.

The larger part of the pig-iron production of this country is converted into steel; 14,947,250 tons represent the total output for last year. Of this, 9,138,363 tons was made by the Bessemer process, 5,687,729 by the open-hearth process, and 121,158 tons was crucible steel.

FINISHED PRODUCTS.

Of the finished products for the year, 2,947,933 tons represent the amount of iron and steel formed into rails. If all this metal were rolled into a single rail of standard proportions, it would measure approximately 81 feet high, and would be about a mile and one-fifth long. The base would, of course, equal the height, and the tread would have a width of 43 feet. In our illustration we have shown the relative proportions of a locomotive of average size, placed on this rail.

Next in quantity to the iron and steel rail production is last year's output of plates and sheets; 2,665,409 tons of metal were thus converted. This amount, if rolled into a single sheet of No. 30 standard gage, which is the thinnest sheet steel commercially used, would cover 420 square miles, or nearly twenty times the area of the island of Manhattan. The extent of this area is illustrated in the accompanying map of New York city and its vicinity.

The production of nails forms no small part of the finished products for the year. Wire nails represent, of course, a much larger part of the output. The totals are 10,982,246 100-pound kegs of wire nails and 1,633,762 100-pound kegs of cut nails. Following the method in our two previous comparisons, we have represented each amount by a single nail of standard proportions. The cut nail would tower far above the Park Row Building, measuring almost exactly the height of the Washington Monument, while the wire nail would rise to nearly double this height, overtopping the Eiffel Tower, and forming a solid column of metal 54 feet in diameter and 1,000 feet high.

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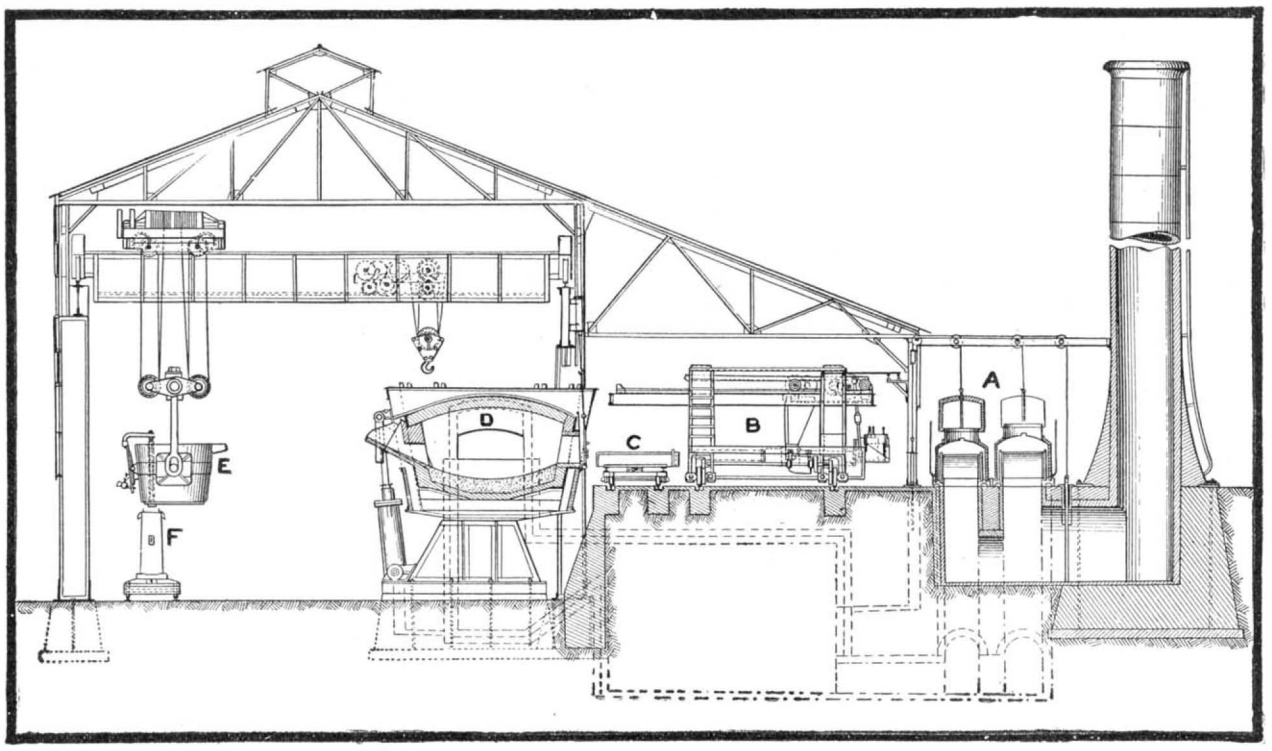
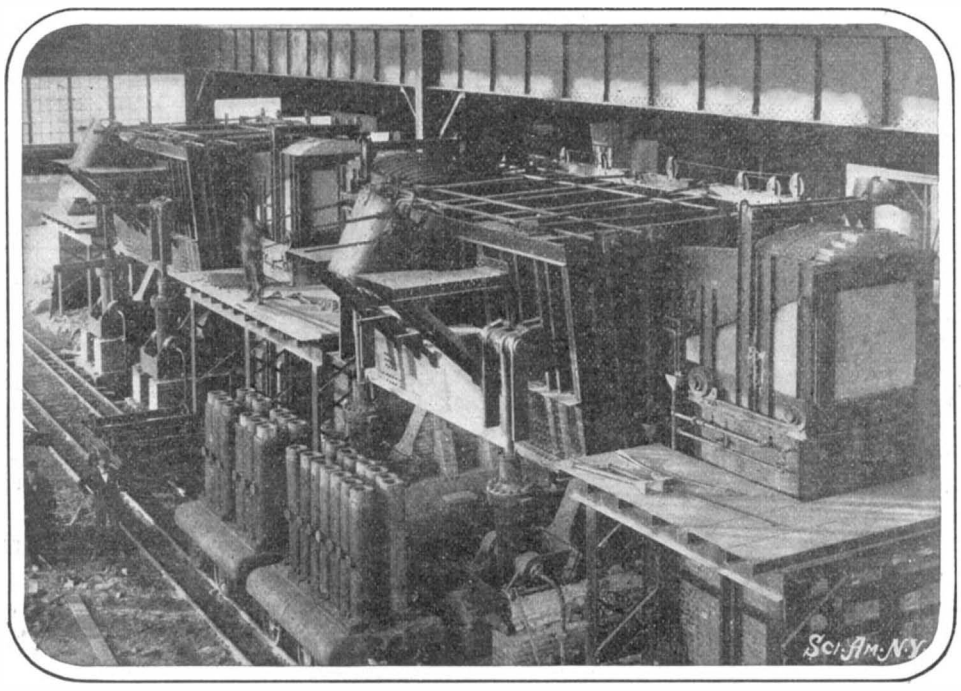
MANUFACTURE OF BRIDGE AND BUILDING STRUCTURAL SHAPES.

It was a wise choice which selected the term "structural shapes" to designate the wide variety of angle-irons, T-irons, I-beams, Z-bars, channel irons and built-up posts, beams, and girders which are used in modern iron and steel construction, for it would be scarcely possible to find any term that would so descriptively apply to every single member of an extremely numerous class of manufactured articles. There is no other branch of the iron and steel industry, perhaps, in which the American citizen has more reason to take pride than this, for upon no other have we stamped our national individuality so deeply. The American bridge and the American composite steel-and-masonry building are two forms of construction that are recognized the world over as having received their most marked development in this country. Of bridge building particularly it may be said that it is to the improved methods of manufacture and of shop management, coupled with a system of design that has an eye always to expeditious and economical work in the construction shop, that the great rapidity and cheapness of construction and erection of American bridges is due. From among the many great "structural" works of the country that make bridge building a specialty, we have selected for the present description the Pencoyd Iron Works, of Pencoyd, Pa. The choice was made for the double reason that these works are among the largest and most representative in this country, and that they are particularly familiar to the American public because of their successful and widely-advertised competition with foreign builders, in which they secured the contract for the construction of the Atbara Bridge in the Soudan.

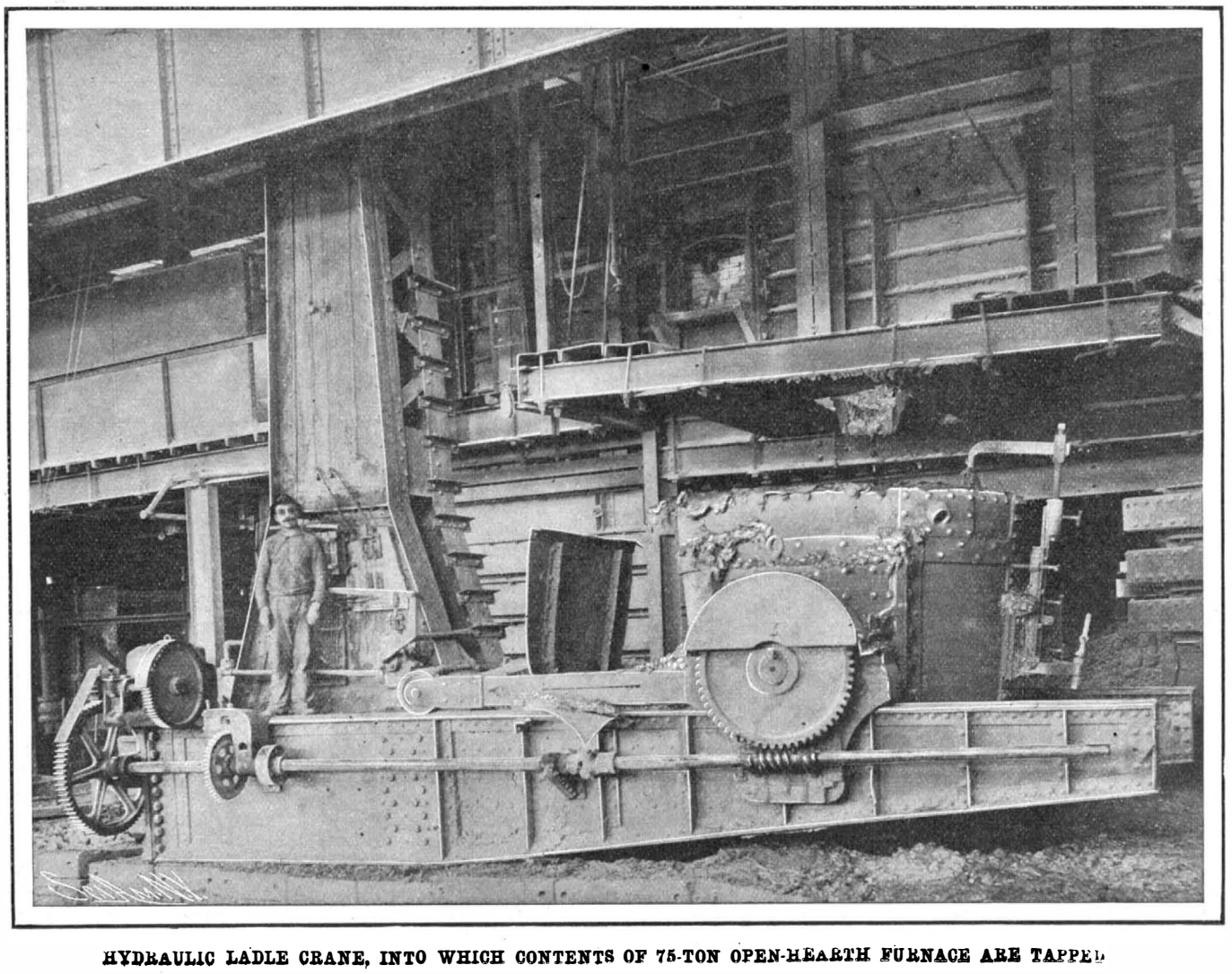


To extreme right is the chimney; then follow: A, air and gas reversing valves; B, charging machine; C, buggies from which charger picks up boxes of "mixture," thrusts them into furnace and empties them; D, Wellman rolling furnace, showing charging door, pouring spout, and hydraulic cylinder for pulling over; E, ladle crane, with its crane in position over a mold for pouring an ingot.

SECTIONAL VIEW, SHOWING RELATIVE POSITIONS OF PARTS OF A WELLMAN OPEN-HEARTH PLANT.



POURING SIDE OF 20-TON OPEN-HEARTH FURNACES, WITH FORE HEARTH IN POSITION.



HYDRAULIC LADLE CRANE, INTO WHICH CONTENTS OF 75-TON OPEN-HEARTH FURNACE ARE TAPPED.

THE OPEN-HEARTH PLANT.—The shapes are rolled entirely from basic open-hearth steel, three grades being produced — "rivet," "soft," and "medium." The rivet steel has an ultimate strength of from 48,000 to 58,000 pounds; soft steel, of from 52,000 to 62,000 pounds; and the medium of from 60,000 to 70,000 pounds. In each case the required elastic limit is not less than half the ultimate strength, and the test pieces of steel must be capable of being bent over upon themselves to an angle of 180 degrees without fracture, while the eye-bars used in bridge construction must show a tensile strength of not more than 10,000 pounds below the test specimen of the grade of steel from which they are rolled. They must also show not less than 10 per cent elongation in the body of the bar, and they must break in the body and not in the eye. The open-hearth plant (no Bessemer steel is made at these works) consists of ten furnaces, each of about 30 tons capacity, and one tilting furnace of 75 tons capacity, the total output of which is 4,600 tons of ingots per week. In the stock yard the raw materials consist of ore, scrap steel (such as junk, crop ends, punchings, and general scrap from the construction shop), and pig iron. The pig is melted in cupolas and run into the open-hearth furnaces, where an equal proportion of cold scrap is added. One of our engravings shows a hydraulic ladle crane into which the contents of the 75-ton furnace are poured, the crane with its burden being then swung around over the casting pit and the hot metal poured into the ingot molds through the bottom of the ladle in the usual way.

ROLLING MILLS.—To take care of the 46,000 tons of ingots turned out every week from the open-hearth department calls for an extensive plant in the rolling mills. This consists of a 23-inch three-high roll train used for rolling shapes; a 12-inch three-high roll train used for small bars, angles, T-irons, etc., and a large 23 to 28-inch mill, comprising a 28-inch two-high reversing roughing mill, and a 23-inch three-high finishing mill, each driven by 30 x 36-inch double reversing engines, geared direct to the mills. In this mill, whose weekly output is from 2,000 to 3,000 tons, angles are rolled up to 190 feet in length, and beams up to 100 feet the blooms from which they are made weighing from 1,150 to 6,000 pounds each. Lastly, there is a 36-inch two-high mill, which prepares the steel for the finishing mills, that has turned out as much as 3,800 tons of blooms and billets per week. When the shapes are rolled they are sawed into the desired lengths, taken to the hot-beds to cool, straightened, and then cut to exact length. The material is now ready for the construction shop.

BRIDGE AND CONSTRUCTION SHOP.—In this department, which is housed in a building 200 feet wide by 460 feet long, great care has been taken to make the operation of building the angles, channels, tees, and various shapes up into finished bridge members

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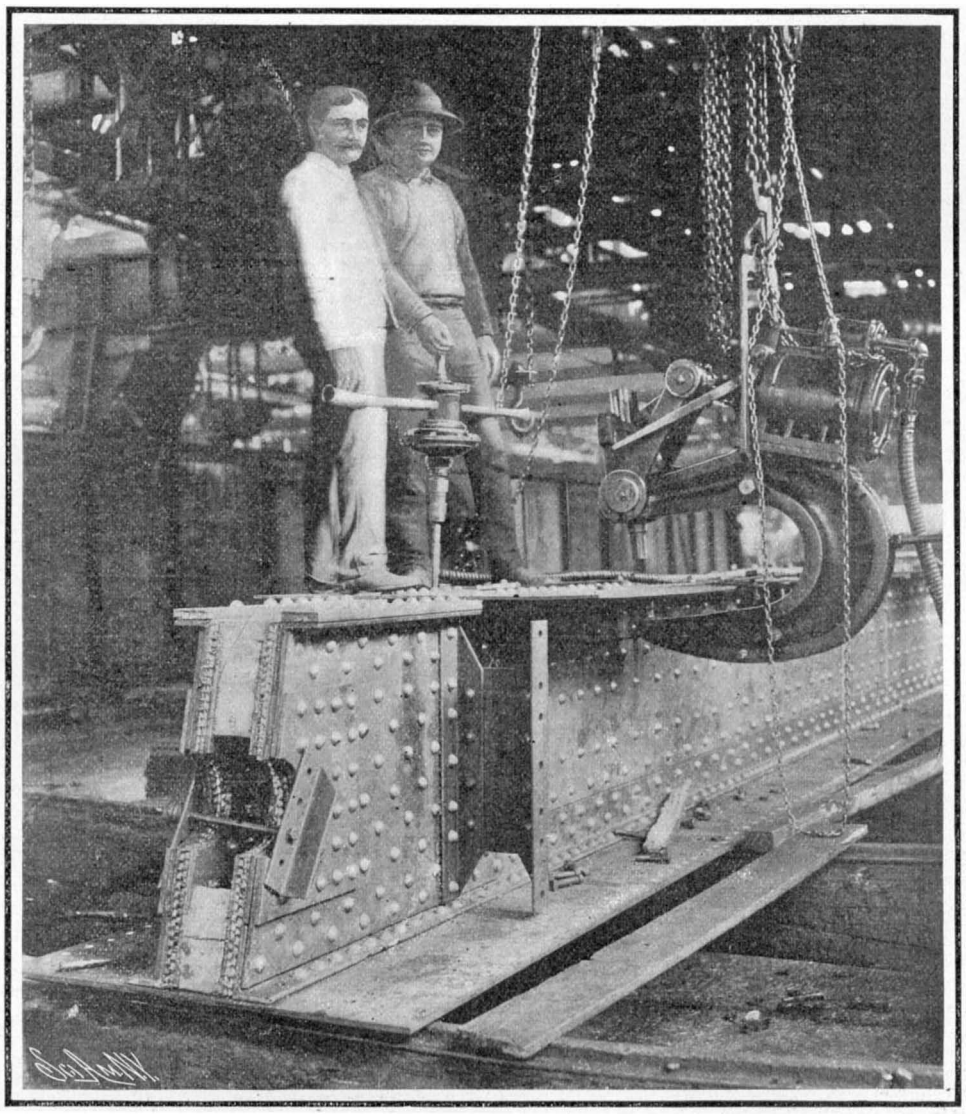
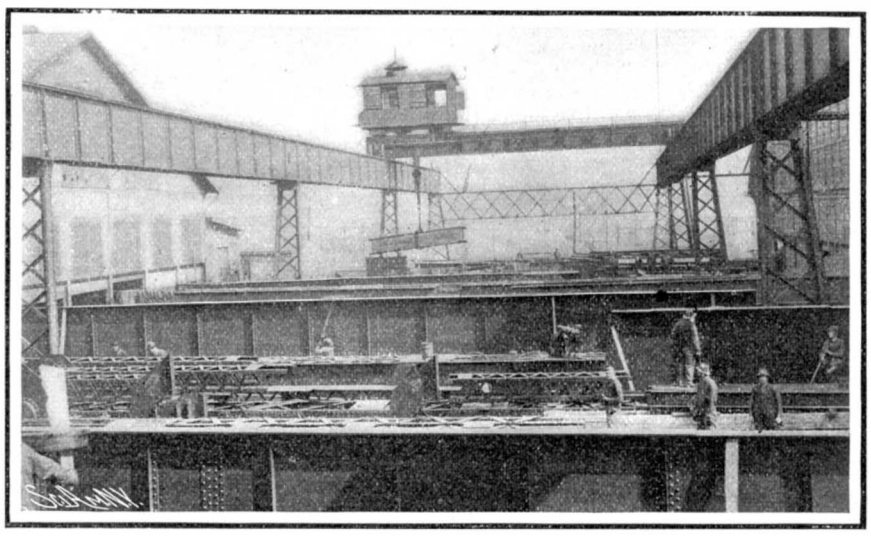
as continuous as possible, with a minimum of handling and transportation. At the end of the shop next the rolling mills the shapes are carefully laid out by wooden templates, in which the exact position of every rivet, angle, gusset, etc., is marked. The operation of building up the bridge material is a simple one, the chief requisites being great care and accuracy. The shapes are sawn or sheared to exact length, and, where it is called for by the drawings, the sides and ends are planed and faced down. All pinholes are first punched and then bored to exact diameters; but the smaller holes for bolts and rivets are punched, and for doing this work some very highly developed machinery, driven by electrical power, has been installed. The preliminary work being now completed, the pieces are assembled, bolted together, rivet holes properly registered (by reaming them if necessary), and finally they are riveted up by hydraulic and pneumatic riveters. One of our illustrations shows a portable pneumatic riveter at work upon a large end post, weighing 30 tons, for a bridge across the Mississippi, and another represents a massive floor beam intended for the same bridge, being riveted in a large under-hung 100-ton hydraulic lift riveter. The development of labor-saving machinery in this shop is an exceedingly interesting study, which limitations of space alone prevent us from taking up at this time. Steam has given place entirely to electricity, practically all of the tools being driven by independent electric motors, while electric power hoists and reamers, pneumatic riveters, and other pneumatic tools are supplied so liberally that it is a rarity to see hand work being done in any part of the shop. As the work is completed, it reaches the opposite end of the shop from that at which it entered, from which it is moved out into the yard for finished material, where it is loaded onto the cars by two overhead cranes of 30 tons capacity and shipped to its destination. The total capacity of the bridge and construction department, including the eye-bar and forge shops, is 9,000 tons of finished material per month. When plans of enlargement have been carried out, the capacity will be raised to about 15,000 tons per month.

EYE-BAR SHOP.—One of the most important branches of bridge manufacture is the construction of eye-bars, and in the shop devoted to this work is found a complete equipment of hydraulic machinery, including pumps, accumulators, an upsetting machine for forming the heads of the eye-bars, and a collection of shearing, punching, rolling, and straightening tools with the necessary heating and annealing furnaces. The upsetting of the eye-bars is done in an ingenious hydraulic machine, in which the heated end of the eye-bar is brought up to the desired circular form by means of a hydraulic press, carrying a three-fold die. The formation of the head is completed in a single operation. The head is then forged and punched at one heat, ready for the finish boring. Eye-bars are formed up in this machine to a size of 8 inches width of body and 18 inches diameter of head. When an order of eye-bars is completed, a full-sized test is sometimes made by pulling one of the bars asunder in a hydraulic testing machine with a maximum capacity of 700 tons.

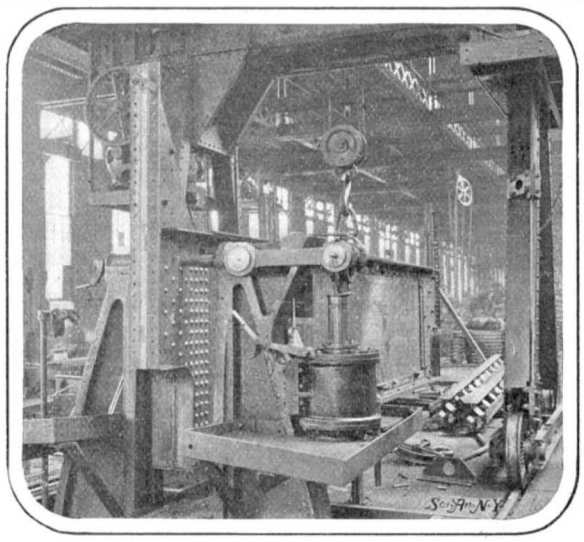
In conclusion we give some facts regarding the rivet and bolt shops. As we have indicated in the opening of this paper, a special grade of steel, known as rivet steel, is used which has an ultimate breaking strength of from 48,000 to 58,000 pounds. The rivets and bolts are made in special machines which turn them out with extraordinary rapidity. Thus, in a single month over 850,000 pounds of rivets and about 220,000 pounds of bolts have been made in this department. As illustrating the remarkable growth of a single typical American bridge and construction works, it may be noted that whereas in 1853, the first year of operation of the works, the total output was 304 gross tons, it had grown in 1860 to 1,475 tons; in 1870 to 6,700 tons; in 1880 to over 15,000 tons. By 1890, the bridge and construction department turned out 26,065 tons and the rolling mill department 48,230 tons; while in 1902 the respective totals were 87,000 and 180,000 tons.



RIVETING UP A MASSIVE 35-TON CHORD SECTION FOR NEW BRIDGE ACROSS THE MISSISSIPPI AT THEBES, ILL.

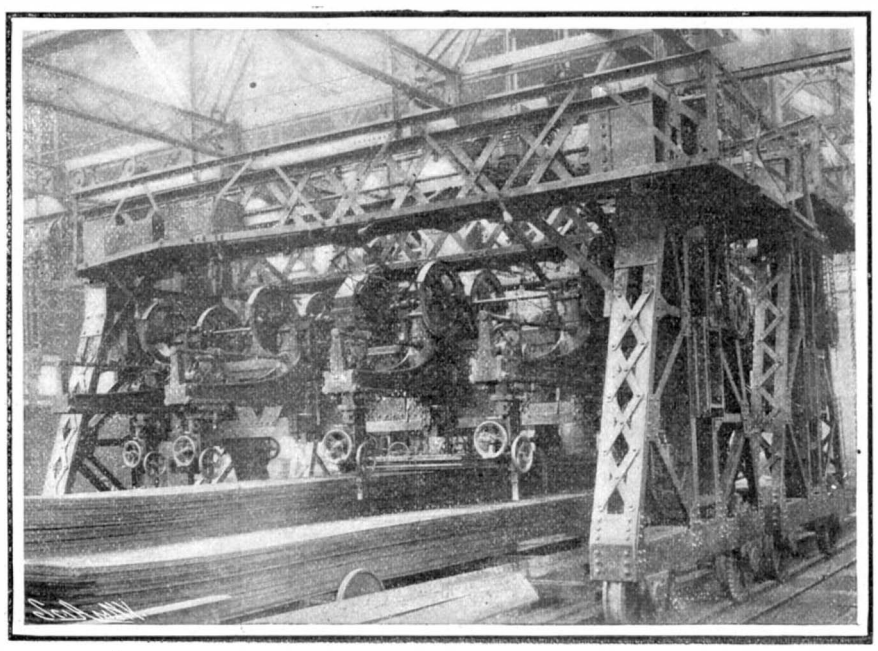


THE SHIPPING YARD, WITH COMPLETED PLATE-GIRDER BRIDGES, READY FOR SHIPMENT.

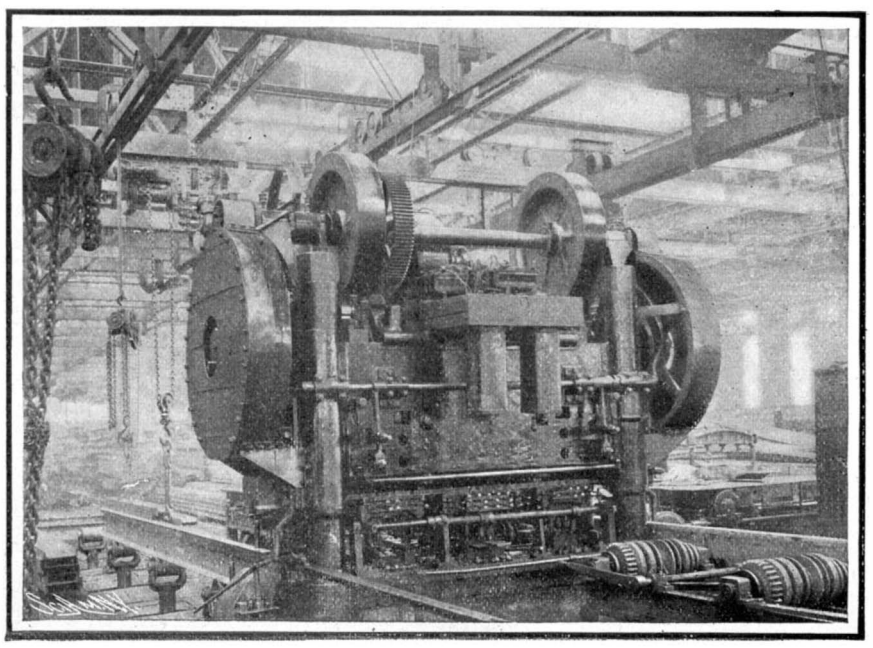


100-TON HYDRAULIC RIVETER AT WORK ON HEAVY FLOORBEAM.

The Trinity House authorities have given notice of several important alterations at the lighthouses on the south coast of England and in the English Channel. The one of the greatest importance to all navigators of the Channel is that relating to the Lizard lighthouses. Here the two fixed white lights hitherto exhibited have been discontinued, and in lieu thereof a white electric light, of great brilliancy, is exhibited from the eastern tower, flashing once every five seconds, and lasting only for a quarter of a second. In addition a continuous light of small power may be visible for about twelve miles under certain circumstances. The subsidiary fixed white light proposed to be exhibited from the eastern tower will not be shown for the present.



A PAIR OF LARGE ELECTRIC GANTRY DRILLING MACHINES, EACH CARRYING EIGHT DRILLS OF FIVE-FOOT RADIUS.



ELECTRIC BEAM PUNCHING MACHINE; WORK IS FED BY MOTOR-DRIVEN ROLLER TABLES AT RIGHT OF CUT.

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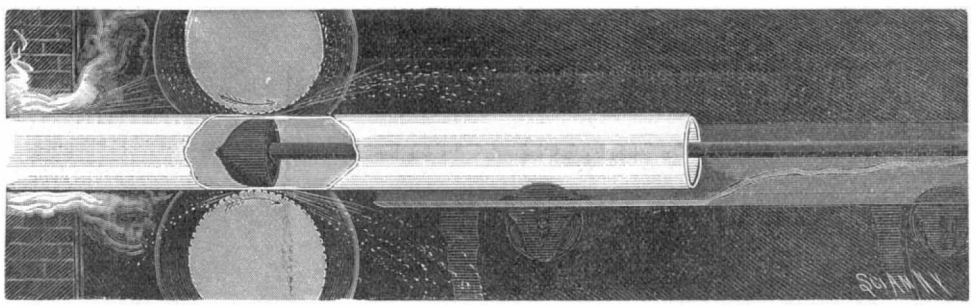
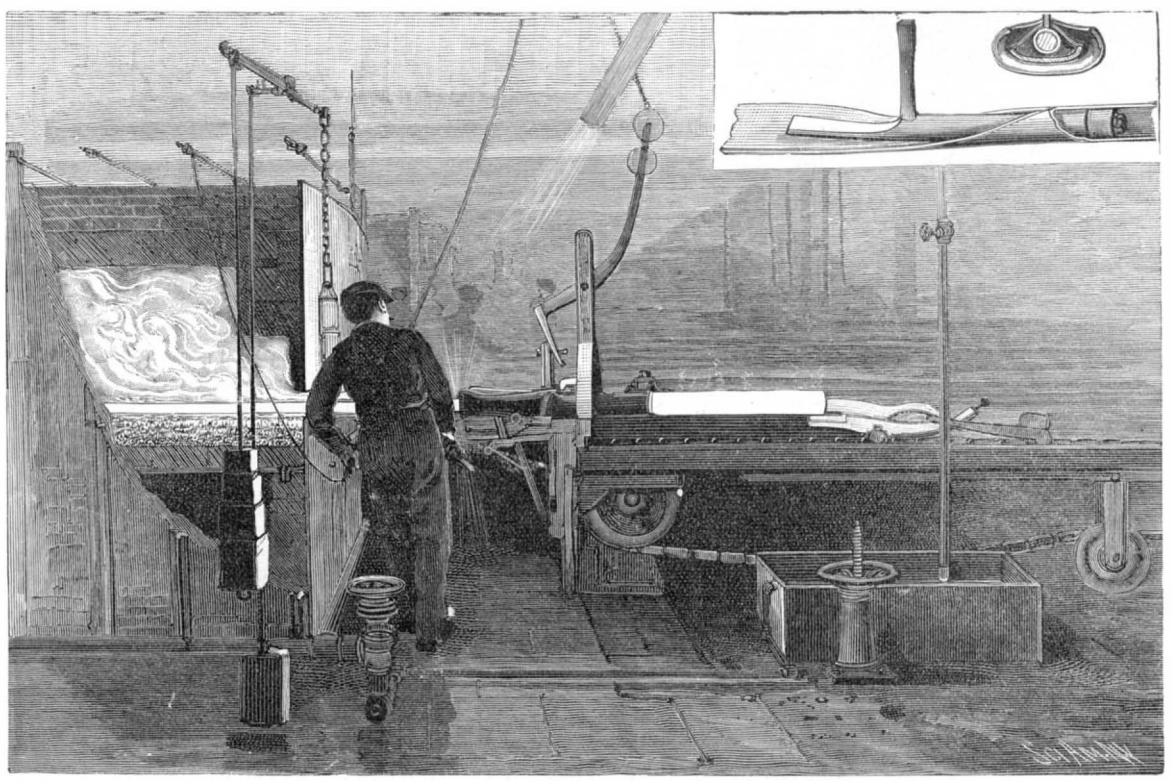
MANUFACTURE OF STEEL PIPE.

The wrought-iron pipe and tube industry was one of the last to discard puddled iron in favor of Bessemer steel. Manufacturers were fully alive to the advantages of strength and low cost presented by the use of steel, but for several years they experienced difficulty in making lap and butt-welded steel pipe that would present the same strength in the weld as in the body of the pipe. Ultimately, after much discouraging failure, the problem was solved, and for several years the market has been supplied with steel pipe and tubing that is as strong, and if anything stronger, at the weld than at any other point.



LAP-WELDING PIPE.

The National Tube Works, whose plant is the largest of the kind in the world, has been selected for the present description of the manufacture of steel pipe. This great establishment covers an area of over 100 acres and gives employment to between 7,000 and 8,000 men. During every working day of the year raw materials are consumed at the rate of 1,200 tons of ore, 1,800 tons of coal, 850 tons of coke and 350 tons of limestone; while the total output of pipe and tubing during the year is about 310,000 tons.

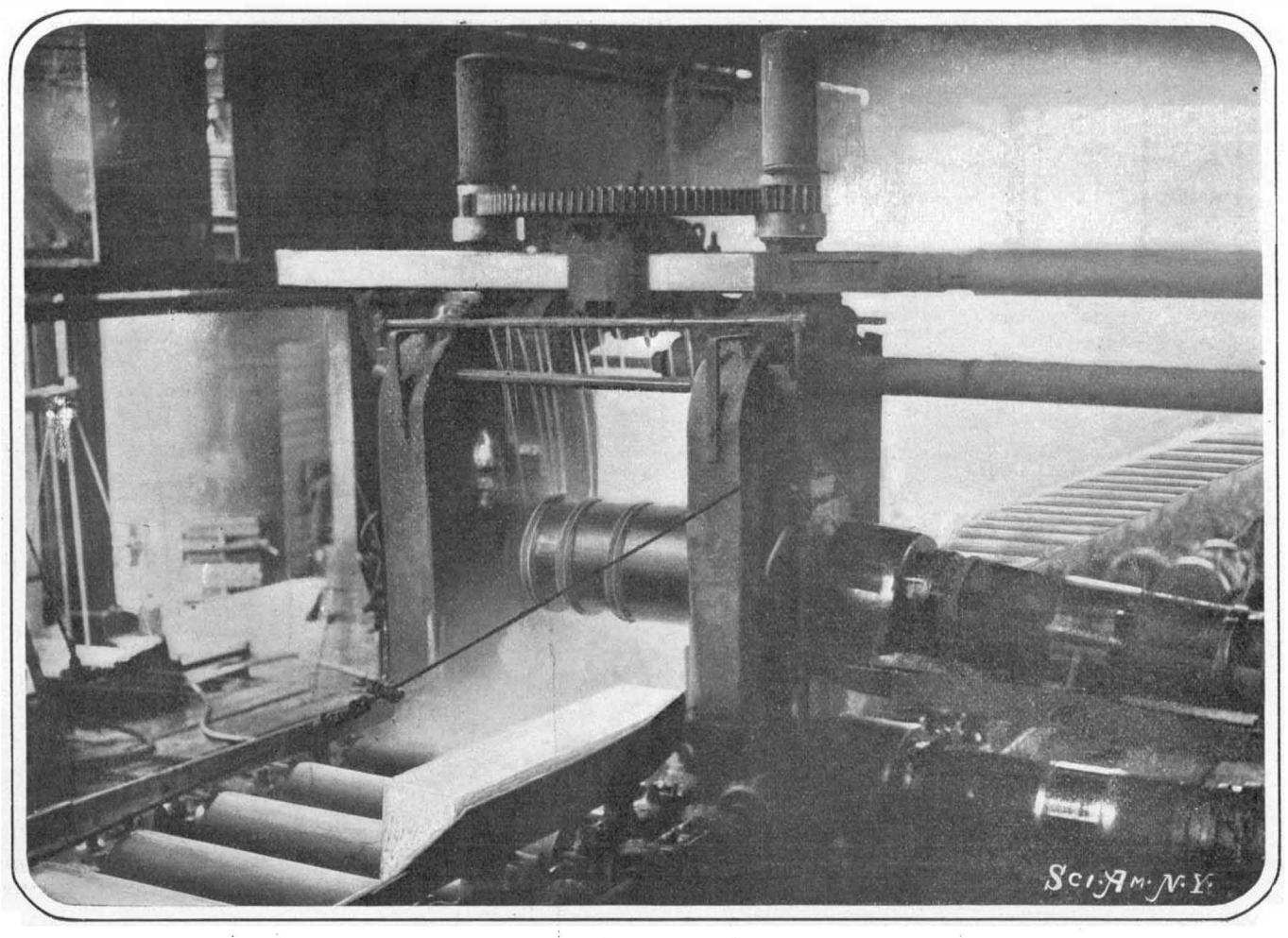


FORMING UP PIPE, READY FOR WELDING.

THE BLAST FURNACES.—In the manufacture of a grade of steel whose most desirable quality is its ability to form a perfectly reliable weld, great care must be exercised in the selection and mixture of the pig iron before it is treated in the converters. For this reason it was deemed expedient for the company to erect its own blast furnaces, and for many years it has ceased to buy in the open market. At present the plant contains two blast furnaces, with a capacity of about 700 tons per twenty-four hours; but this department, like many others in this plant, is now being doubled. As the metal is tapped it is taken in ladles to a straight-line casting machine, where it is cast into pigs. A test specimen of each cast is carefully analyzed, and a record of its composition kept, and when the cupolas in which the cast iron is melted down for treatment in the converters are charged, the pig is selected from different casts with reference to its composition, so that the molten cast iron as it is poured into the converters will have the desired proportions of silicon and sulphur.

THE CONVERTERS.—The pig iron is melted down in three cupolas 10 feet in diameter and 30 feet in height, the charge consisting of graded pig iron, coke, and limestone. These cupolas are in continuous operation; and as the iron melts it is drawn off and taken to two 8-ton Bessemer converters, one of which is shown in our front-page engraving. Experience has proved that in order to secure thoroughly reliable lap and butt-welded tubing it is necessary to produce a special quality of mild steel, in which it is most important to secure the proper proportion of carbon; and this is secured by exercising the greatest care during the converter treatment. During the first three or four minutes of the process, the graphitic carbon in the cast iron is changed into combined carbon, and the silicon combines with the oxygen of the blast in the form of silica, which in its turn forms slag, by combination with the iron and manganese. During these changes there is a great increase in the volume and brightness of the flame that rushes from the converter's mouth, and the temperature rises until the second stage, known as the "boil," is reached. This lasts for about eight minutes, during which time the volume and brilliancy of the flame further increase, and vast showers of burning iron and incandescent slag are thrown from the mouth of the converter, at times with an explosive effect. When the boil is completed the flame dies down considerably, and takes on a faint rosy tint, the shower of sparks becoming less violent. This is known as the "fining" stage, and lasts for a few minutes. At the conclusion of the process, when practically the whole of the carbon has been burned out of the charge, the flame suddenly dies away, indicating that the iron has been purified and rid of its carbon. The metal is now poured into the casting ladle, and a certain amount of ferromanganese is run into the same ladle to give the desired proportions of manganese and carbon.

BLOOMING MILL.—The metal is then cast into ingots, which are heated in the soaking pits and rolled down into blooms in the blooming mill. This mill, which is of massive construction (see illustration) is driven by a pair of horizontal reversing engines of 3,000 horse power. On each side of the rolls is a long table of rollers which, like the rolls of the mill, are reversible. The white-hot ingot, weighing 2½ tons, is picked up out of the soaking pit by an overhead electrical crane, and placed upon the table, which, by the action of its rollers, runs the mass quickly into the rolls. As soon as it has passed through, the engines are reversed, the rolls being brought a little closer together by means of a pair of massive screws set in the standards, and the ingot receives another reduction in thickness. This is repeated until it has been brought down to the desired section, when it is sheared into short lengths, known as slabs and billets.



BLOOMING ROLLS IN WHICH THE 2½-TON INGOT IS ROLLED DOWN INTO BLOOMS.

THE CONTINUOUS SKELP MILL.—These are reheated and are rolled down in a continuous mill into long thin sheets known as skelp. The continuous mill, which is 300 feet in length, is of particular interest, not only as being one of the largest of its kind in existence, but also as being the first of its type to be erected in this country. The continuous mill consists of a large number of successive pairs of rolls, placed one beyond the other, with increasing intervals between them. The billet as it is carried through each pair is reduced in thickness and increased in length, until it issues from the last pair of rolls in the form of a long, narrow plate known as skelp. The skelp is rolled in sizes from the thin, narrow strips for smaller pipes up to the great sheets, about 8 feet in width, which are needed for a 30-inch pipe. In the smaller sizes of pipe, the width of the skelp is sufficiently uniform to dispense with the necessity of trimming up with the shears; but the skelp for large piping has to be carefully trimmed down to the right dimensions.

THE PIPE MILLS.—Broadly speaking, all the tubing manufactured at this establishment may be divided into two classes, butt-welded and lap-welded; the former including all tubing from ⅛ inch up to 1¼ inches, and the latter all sizes from 1½ inches up to 30 inches. In the butt mills in which small gas and water pipe is made there are six welding gas furnaces, while in the lap-welded mills there are ten bending gas and twelve welding gas furnaces,

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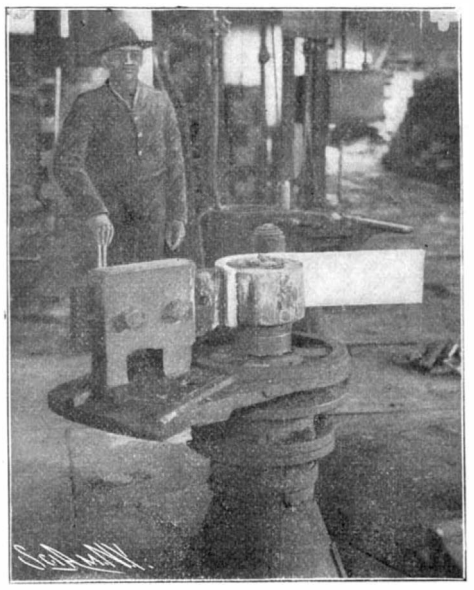
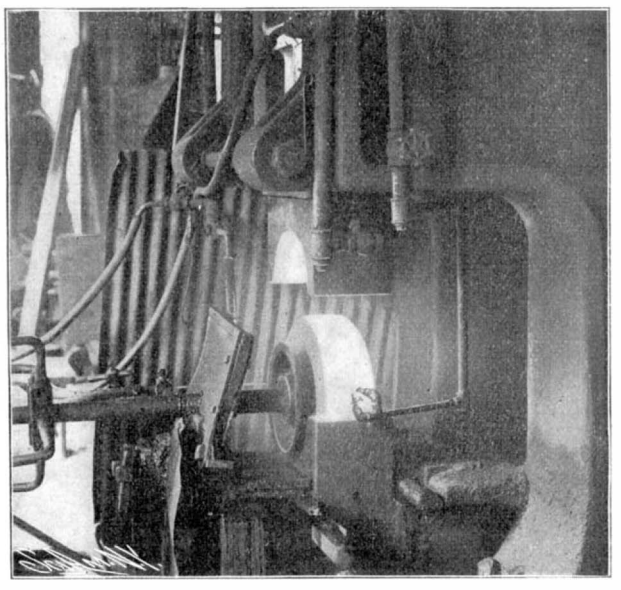
LAP-WELDING.—The plates for the larger sizes of pipe are first laid upon a traveling table, and the edges scarfed or beveled. It is then heated in a bending furnace and rolled up into pipe form with the scarfed edges overlapping. The plates for the smaller sizes are formed up by being drawn through the die shown in the accompanying illustration. This consists of a stout cast iron bending die, the front half of which next the furnace door is flared out to receive the plate. Inside the die is a mandrel of the shape shown in the smaller engraving, whose rear portion is of about the size of the finished pipe. As the plate is pushed out of the furnace it is drawn by a pair of tongs through the die, the flaring sides of which curve the plate until its edges meet and lap as they pass through the tubular end of the die. The plates, now bent up into form and known as skelp, are heated in a gas-fired welding furnace, and when they have reached a welding heat the skelp is pushed through the door at the back of the furnace into the welding rolls, which are located just outside the door. The rolls, which are concave, are curved to the desired radius, and between them, held in position by a long bar, is a "ball" or mandrel of the same diameter as the inside of the pipe. As the skelp passes through the rolls, its lapping edges are squeezed together between the rolls and the mandrel, and a perfect weld is made. Each piece of pipe is carefully examined, and all doubtful welds are rejected. The rough pipe then goes through the sizing rolls, in which it is brought to exact diameter. Then it passes to the cross-straightening rolls, the axes of which are inclined at an angle, as shown in the accompanying illustration. By this time it is perfectly true and straight, and to prevent it from warping as it cools, it is rolled and conveyed on a cooling table to a straightening machine, where it receives its final straightening in dies controlled by hydraulic pressure. The ends are then cut off, and after being threaded and the coupling put on, the pipe is tested in a hydraulic testing machine, the smaller sizes at from 600 to 1,500 pounds, the larger at from 500 to 750 pounds to the square inch. For oil-well tubing the tests run as high as 2,500 pounds to the square inch.

BUTT-WELDING.—The smaller sizes of pipe are butt-welded. The plates, which are not scarfed as in the larger pipe, are heated in the furnace, and when raised to a welding heat are drawn through a bell-shaped die, the diameter of which is a little less than that of the skelp. The pressure thus induced is sufficient to squeeze the edges together, and form the plate into a perfectly welded pipe.

WELDING FLANGES.—The smaller sizes of pipe are fitted with screwed flanges and couplings, and at one time these were used on all sizes of pipe. Of late years, however, the company has succeeded in welding the flanges on the pipe and producing results that are as satisfactory as the welding of the pipe itself. The flange for the larger pipes is formed out of a bar of steel, bored out, and faced on the inner face, a half-inch fillet being left on the inner edge. The end of the pipe is swaged down slightly, the flange pushed on over it, and the edge of the pipe beaded over to keep the flange in place in the furnace. When the work has reached a welding heat, the pipe is swung onto a cone anvil, which is stepped to receive both pipe and flange. The pipe is turned around on the anvil under the repeated blows of the hammer, and the welding up is quickly completed. Flanges have been welded onto pipes of upward of 30 inches diameter with satisfactory results.



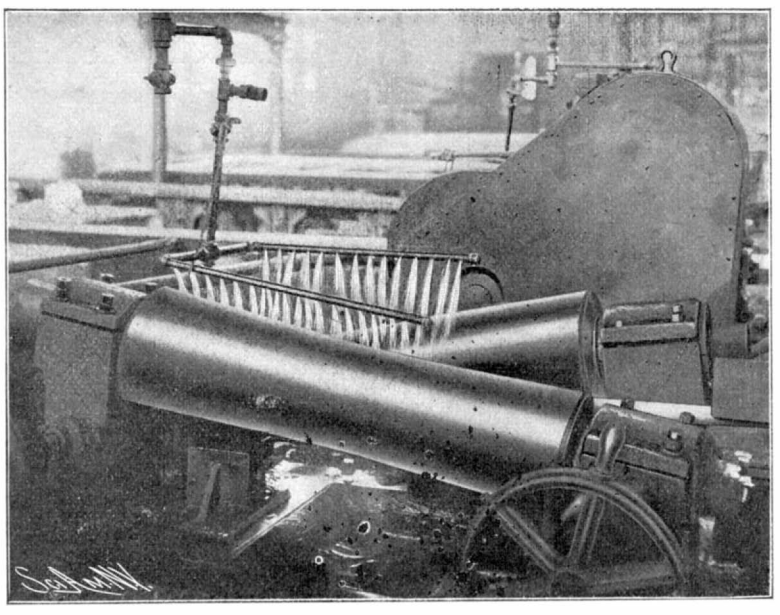
FORMING PIPE COUPLINGS.



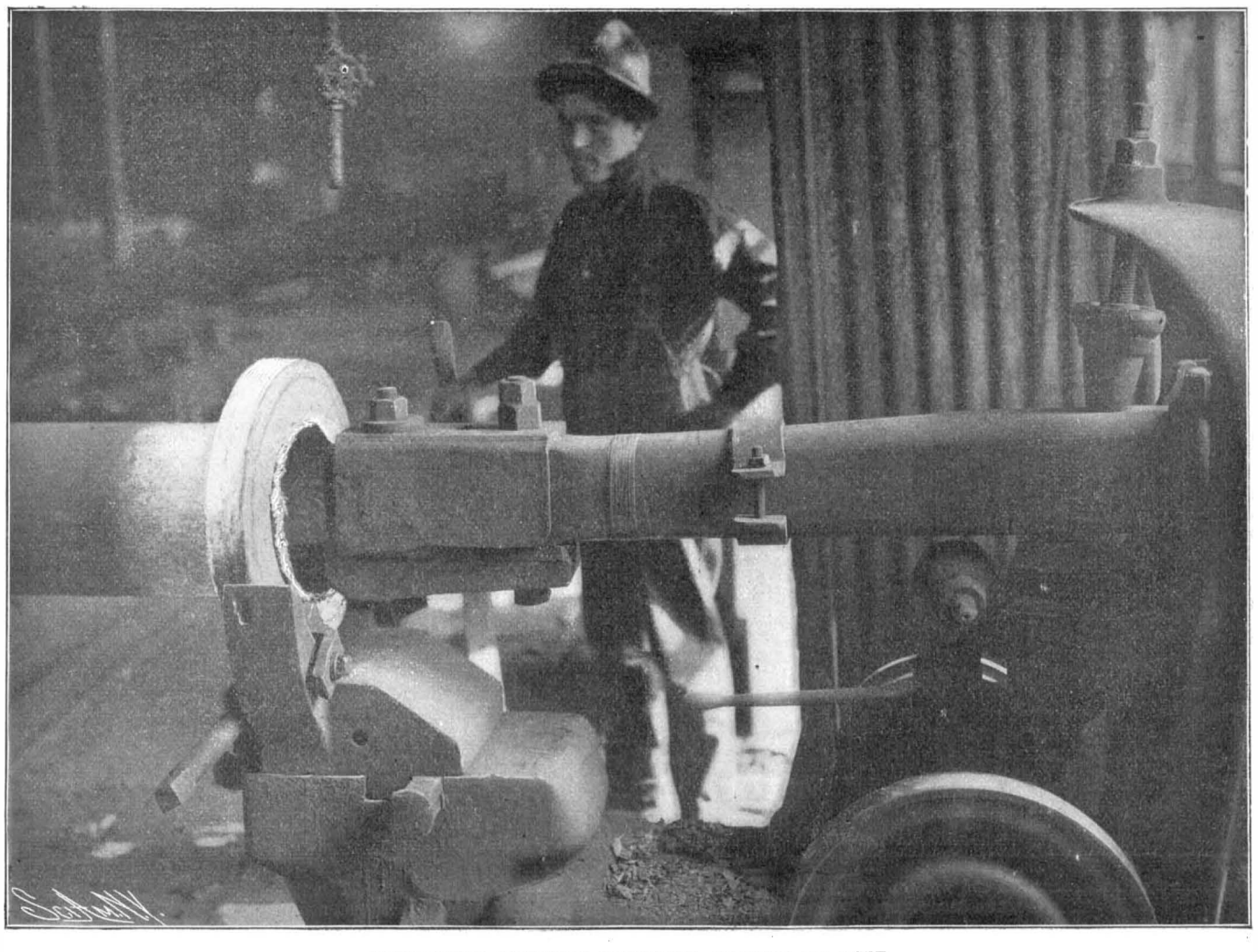
WELDING PIPE COUPLINGS.

MAKING PIPE COUPLINGS.—Pipe couplings are manufactured from bars of iron of about the thickness and width of the coupling. The smaller sizes are made in a special machine, which cuts off the desired length of bar iron and forms it up on a mandrel with wonderful rapidity. The pieces are then heated in a welding furnace, and welded under a quick-acting steam hammer. The larger sizes are formed from bar iron, which is cut into the desired length, the pieces being formed up on the interesting machine shown in the accompanying engraving. This consists of a vertical, cylindrical mandrel of about the size of the desired coupling, and around this mandrel travels, at the end of a horizontal arm, a vertical roller. The heated bar is placed against the mandrel and gripped firmly against the latter at one end. The vertical roller then describes a circle around the mandrel, bending the heated bar into the circular form and to the required diameter. The piece is then raised to a welding heat, slipped onto a cylindrical mandrel, and welded under a quick-acting steam hammer shown in the accompanying illustration.

SEVERE TESTS.—In view of the large amount of welding that enters into pipe manufacture, the most severe tests are continually being applied to the material during and after manufacture. In addition to the hydraulic tests, the rough ends cut from the pipes are subjected to a longitudinal crushing test; and in case of failure at the weld, the tube from which the specimen was cut is sent back to be rewelded. Other tubes again are rolled with an expander and the ends beaded over. Some are cold-flanged, while others again are subjected to a transverse pressure until the section of pipe has been completely flattened out. If the metal stands these cold tests without fracture, it is considered that the lots from which they are taken are up to the high standard required.



STRAIGHTENING ROLLS, IN WHICH PIPE IS STRAIGHTENED AND SMOOTHED.



AUTOMATIC HAMMER WELDING FLANGE ON PIPE.

Work will soon be begun at the Maryland Steel Company's Sparrow's Point plant for rolling 20,000 tons of rail for the Hamadie du Hedjaz Railroad, which runs between Beirut, on the Mediterranean coast of Turkish Asia Minor in the direction of Mecca, Arabia, the shrine of all the world's millions of Mohammedans. The road is being extended to Mecca rapidly and it is probable that before long pilgrims from India, Turkestan, Morocco, and the Soudan will journey to the tomb of Mohammed over a steel pathway made in Maryland. The contract calls for the delivery of the rails at Beirut at $22.88 a ton. This is surprising, inasmuch as the domestic price for steel rails has been $28 a ton, loaded for transportation at the manufacturer's plant.

French exhibits at the World's Fair next year will number five thousand, as against three thousand at the Chicago Fair, and will excel in general interest and completeness any previous French display. They will include an elaborate exhibit of the government's furniture, Gobelin and Beauvaise tapestries, Sevres pottery, laces, silks, educational methods, farming, mining, and industrial exhibits.

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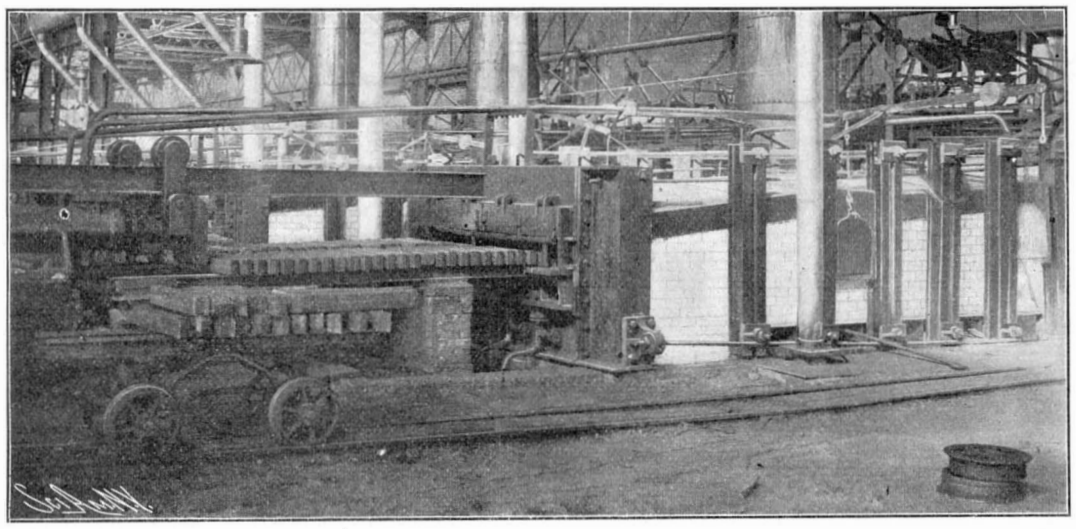
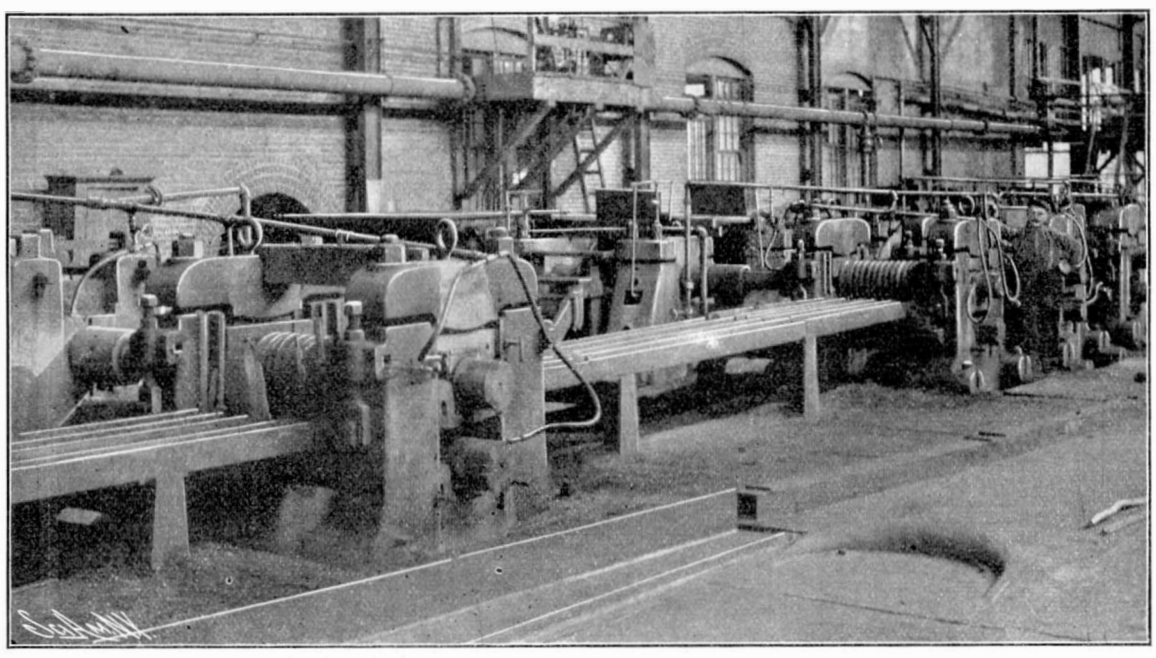
STEEL WIRE AND NAIL MAKING.

The magnitude and importance of the wire and nail industry in the United States may be measured by the fact that in the year 1902 the mills turned out a total of 1,574,293 tons of wire rods, of which nearly half a million tons were made into wire nails. Time was when both wire and nails were manufactured entirely from wrought iron, and to secure the toughness and high tensile strength required, great care had to be used in the preparation of the iron, the cost of the product being proportionately high. It was only a question of time before steel, because of its less cost and its high strength, became the standard material in this as in other branches of the iron and steel industry; and to-day practically the whole of the wire and wire nails used are made from either Bessemer or open-hearth steel, the latter being specified where wire of the special grades with higher physical properties is required.



Continuous Heating Furnace in Which the Billets are Heated for Rolling in Roughing Mill.

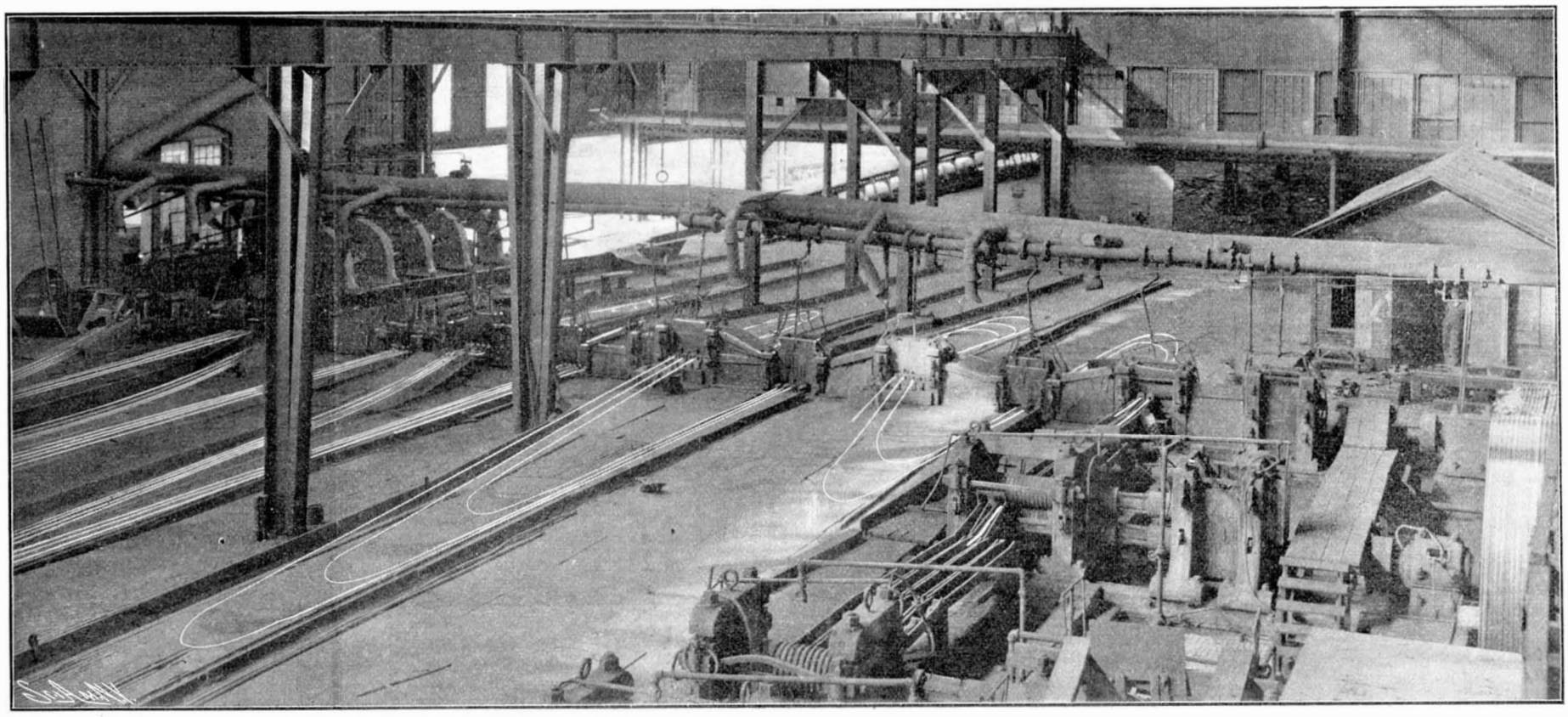
PHYSICAL PROPERTIES OF STEEL WIRE.—As showing the great increase in strength of steel over iron wire, it may be mentioned that while good black iron wire will show an ultimate tensile strength of about 25 tons to the square inch, and bright hard-drawn wire a strength of 35 tons to the square inch, Bessemer steel wire will stand a strain of 40 tons and open-hearth steel wire 60 tons to the inch. Of the "special" grades of wire a high-carbon open-hearth steel will stand about 80 tons, crucible cast-steel wire about 100 tons, and the best cast steel, or as it is sometimes called, "plow" steel wire, 120 tons to the square inch; while certain qualities of cast-steel wire, made under specifications calling for a particular composition, and requiring very elaborate working, have been produced, showing an ultimate breaking strength of from 150 to 170 tons to the square inch. The process of wire drawing, as will be explained later in this article, serves to greatly improve the physical qualities, and the smaller the size to which the wire is drawn down, the greater is the ultimate breaking strength. The wonderful qualities of piano wire are proverbial, the average strength of English piano wire as given by the manufacturers ranging from 225 pounds for No. 12 music wire gage, which is 0.029 inch in diameter, to 650 pounds breaking strength for No. 22, which is 0.052 inch in diameter. Reduced to the square-inch unit, the ultimate tensile strength per square inch would range from 300,000 pounds to 340,000 pounds. The composition of this remarkable wire is as follows: Carbon, 0.570; silicon, 0.090; sulphur, 0.011; phosphorus, 0.018; manganese, 0.425. An analysis of another wire of unusual strength known as "plow," showed 0.828 per cent of carbon, 0.587 per cent of manganese, 0.143 per cent of silicon, 0.009 per cent of sulphur, 0.030 per cent of copper, and no phosphorus. The tests of this wire ran from 200,000 pounds per square inch for wire 0.191 inch in diameter to 350,000 pounds for wire 0.093 inch in diameter. Of course, with such high tensile strength the elongation or stretch was very small, ranging from 0.75 to 1.1 per cent only.



The 8-pass Roughing Mill in Which the Billets are Rolled Down From a 4 x 4-inch to a ¾-inch Square Section.

BILLET YARD.—In describing the manufacture of steel wire and wire nails as carried on at the Donora Works of the American Steel and Wire Company, we shall commence our description at that point of the process where the steel has been manufactured into billets, ready for the rod mill. These great works buy nothing in the open market and carry out the whole process of wire manufacture from the smelting of the ore to the final drawing of the wire; but as we have so completely described, in previous articles in this issue, both blast furnace practice and the conversion of the cast iron into steel either in the Bessemer converter or the Siemens-Martin open-hearth furnace, it would be superfluous to go over the ground again. We shall, therefore, commence at the billet stockyard, where the steel is stored conveniently to the heating furnaces of the rod mill. The bulk of the wire and wire nails of commerce are manufactured from Bessemer billets. Open-hearth billets are worked up into rods for the manufacture of chain, for special grades of wire, and for various finished products in which high tensile strength is called for. At the upper end of the rod mill are four billet continuous-heating furnaces, with a fifth in reserve. When the mill is in full operation, four furnaces are continually at work. The billets, which are 4 x 4 inches in section and 36 inches in length, are fed transversely into the furnace, side by side, as shown in the accompanying engraving. They are pushed through the furnace door by a hydraulic charging machine, and by the time they have been heated to the proper temperature for rolling, they are pushed one after the other out through the rear door of the furnace, and fall upon a conveyor, by which they are carried down into the rod mill. It should be mentioned that two of these furnaces are fed by producer gas and two by natural gas, which is drawn from a well on the company's premises, the former gas being supplied by five Laughlin producers.

ROUGHING MILL.—The roughing mill consists of eight pairs of rolls, in which the billet is reduced from a 4-inch x 4-inch section to a ¾-inch square section, and it is in this mill that the steel receives the first installment of that thorough mechanical working which



To the right are seen the three last pairs of rolls of the roughing mill, with two rods passing through them. Extending to the left across the building are the ten sets of finishing rolls with several wire rods following a serpentine course through them. Wire rods are rolled in this mill at the rate of 776 miles in a single shift of 11 hours.

WIRE-ROD FINISHING MILL.

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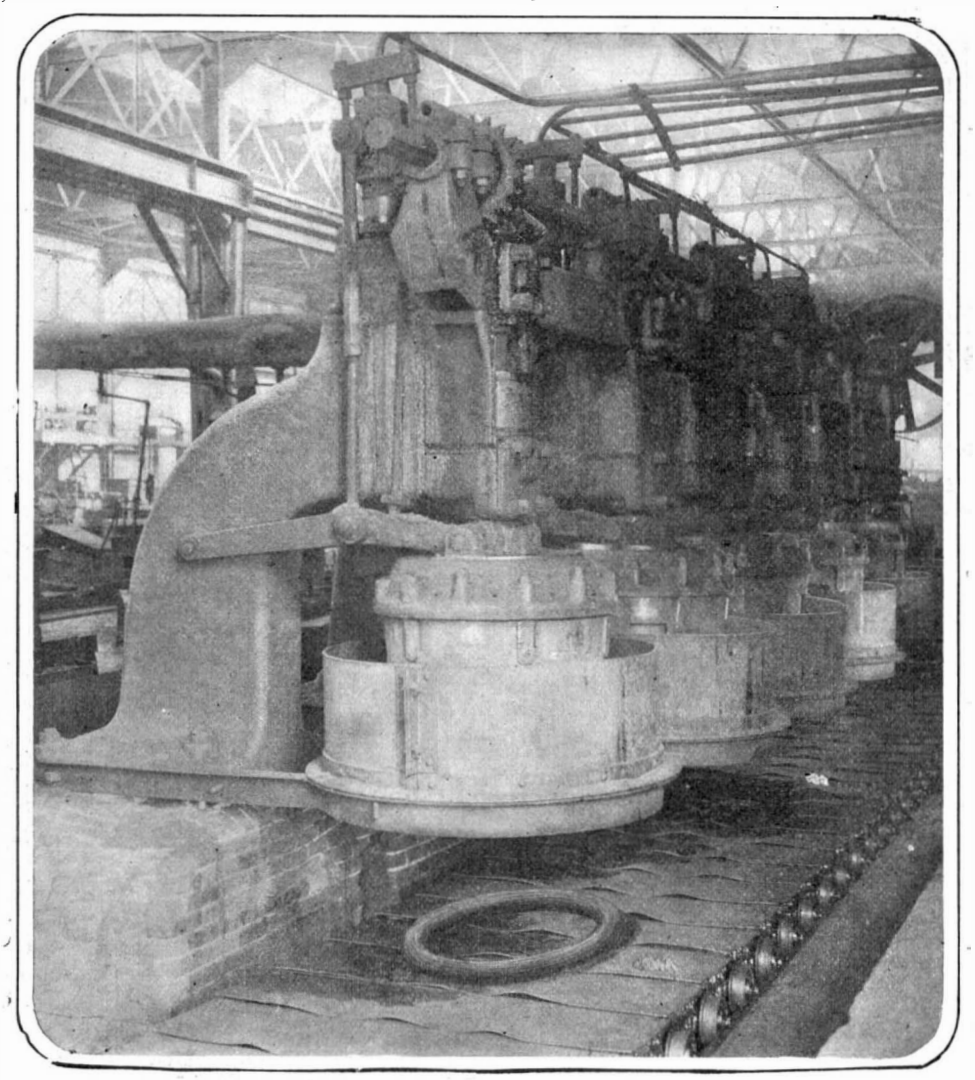
contributes so greatly to its ultimate tensile strength. The arrangement of the mill is shown very clearly in our engraving. Each pair of rolls is placed at an increasing distance from the one that precedes it, in order to allow for the increase in length due to the decrease of section of the billet. It has been found, moreover, that by changing the shapes of the grooves in the successive pairs of rolls, making them alternately square and oval, oval and round, etc., there is not only an economy of power secured, but a more thorough working or manipulation of the metal is obtained, and its qualities are proportionately improved. In the eighth set of rolls, or "pass," as it is technically known, the grooves are three-quarters of an inch square. From these, the last pair of roughing rolls, the rods diverge, some of them being carried to the left, to what is known as No. 1 finishing mill, and others to the right, where they are run through No. 2 finishing mill. The accompanying illustration at the bottom of the page, taken from the upper end of the roughing mill, shows the No. 1 finishing mill, in which the wire rods are given ten more passes and brought down to the required dimensions. The finishing mill lies at right angles to the roughing mill; and instead of the rods passing through pair after pair of rolls in a continuous straight line, they pass through the successive rolls in alternating directions, describing half-circles between each pair, as shown in the illustration. In order to guide the rods into the proper rolls, workmen stand between each pair, and as the rod issues from the rolls it is seized with a pair of tongs, bent around through a half-circle and fed to the next "pass." Consequently, when a rod mill is in full blast, it presents one of the most curious and attractive sights that can be seen in any rolling mill. Owing to the rapid decrease in section and increase in length, as the rod passes through the successive rolls, it is necessary that the speed of the successive rolls be increased; and by the time the rod issues from the tenth roll of the finishing mill, it is traveling at a speed of 1,350 feet per minute, or about 15 miles an hour. Owing, moreover, to the increasing length of the rods as they are rolled down, it happens that although only about two rods at a time are passing through the first of the ten rolls, there will be three or four rods at the fifth or sixth roll, and as many as five or six rods at a time speeding through the tenth or last roll. As the whole of the rolling down from the 4-inch x 4-inch billet to the finished rod, which will be say 13-64 of an inch in diameter, is done at one heat, it can be understood that the scene, when the whole mill is running at full speed, and the white or red-hot steel is winding its serpentine way through the mill, is extremely picturesque, and when seen for the first time, decidedly bewildering. In order to protect the men who stand between the pairs of rolls and direct the course of the rods, a series of curved semi-circular guards or shields are fastened upon the iron floor of the mill, as shown in our engraving, where the course followed by the rods is indicated by a series of white lines. The amount of working to which the steel is subjected in the mills, and the great horse power that is required to perform this duty, may be judged from the fact that the billet, which at the first pass through the mills was 4 inches x 4 inches in section, and only 3 feet long, as it issues from the last pair of rolls is a scant quarter of an inch in diameter and measures no less than 1,189 feet, or not far from a quarter of a mile in length. As the rods leave the last pair of rolls, the ends are caught up and attached to the drums of a set of six Garrett reels, on which they are wound up into a convenient coil for further handling. As soon as the coil is completed, it is dropped from the reel onto the floor of a conveyer, by which it is carried to the wire mill.

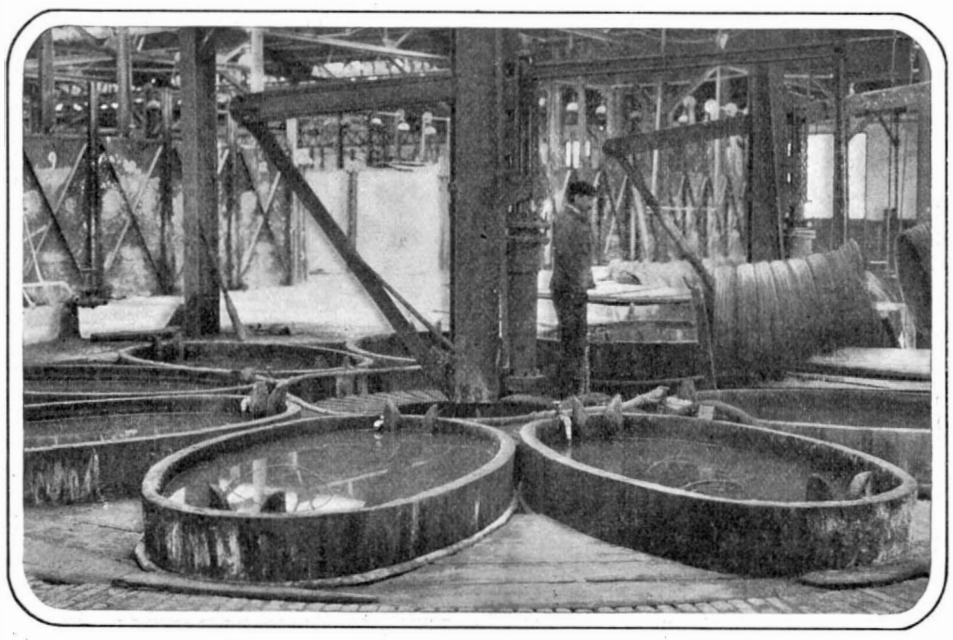


As they are completed the coils are dropped on to conveyer and carried to wire mill.

Drums on Which Wire as it Comes From Rod Mill is Wound Into Coils.

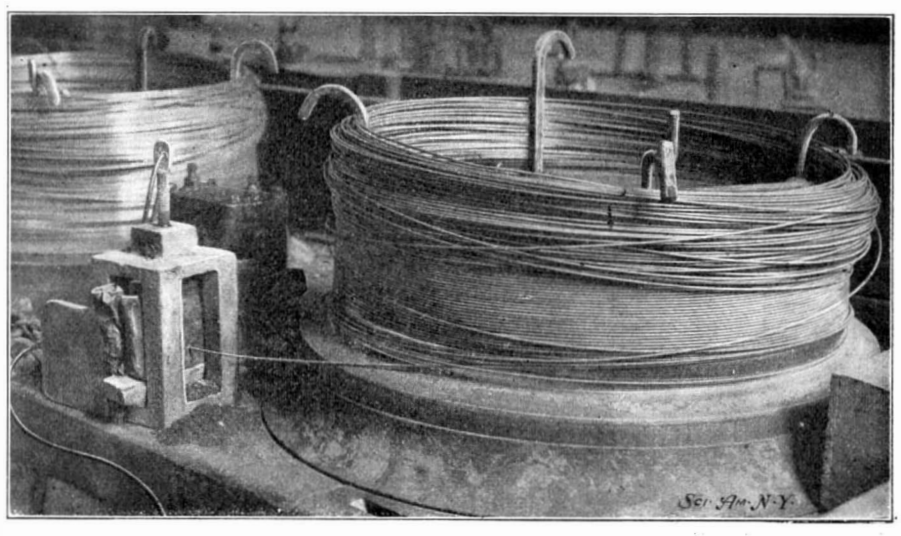
WIRE MILL. CLEANING DEPARTMENT.—The first operation in the wire mill is to thoroughly clean the wire, ridding it of scale, oil, dirt, etc. This is done by immersing the coils in wooden vats containing a weak solution of sulphuric acid. The coils are strung on a stout piece of timber, which is lifted by a hydraulic crane and dropped into the vat. There are six of these vats arranged as shown in our illustration. From the vats the coils of wire are lifted and hung upon a circular rack, where they are allowed to slightly oxidize on the surface, the object of the rust being to render it possible to get a good grip upon the wire in the process of drawing it down. The coils are then placed in a bath of lime, which serves to prevent further oxidation, and also to give a slight coating of lime, which will act as a lubricant to the wire in passing through the dies. Next the wire is placed on trucks and taken to the bakeries, where it is dried out thoroughly.

WIRE DRAWING.—Up to this point the product is known by the technical name of "rods," and it is only after it has been drawn down in the dies that it is known commercially as "wire." Wire drawing is of quite ancient origin, for about the year 1300 A. D. wire was made by pulling it through draw plates. There are descriptions extant of wire-drawing machinery which were published in the sixteenth century, and after that date it gradually took the place of the older method of hammering out the wire by hand, which dates back to some eight hundred years before the Christian era. Wire drawing has the advantage of permitting the production of a much smaller wire than could be produced under the rolls, while the very process of drawing down the wire greatly enhances its physical qualities, increasing the tensile strength to a truly remarkable degree. The wire-drawing machine consists of a stout bench, on which is mounted a strong cast-iron drum, on which the wire is wound as it is drawn through the plate. The draw plates, or die plates, as they are called, are stout blocks of cast steel which are perforated with conical holes, carefully gaged to the exact desired size of the wire. The holes have a slight taper, the wire, of course, entering at the larger end of the hole. The coil of wire is placed on a spool located on the floor of the shop near the bench, and the end of the wire having been swaged down, it is passed through the die plate and attached to the drum, which then



Vats of Dilute Sulphuric Acid in Which Wire is Cleaned Preparatory to Wire-Drawing.

Annealing Room, Where Wire is Subjected to Steady Temperature for Several Hours to Remove Strains.



Wire is Drawn Down Through a Hole in Hardened Steel Plate and Reduced to the Finished Size.

WIRE DRAWING.

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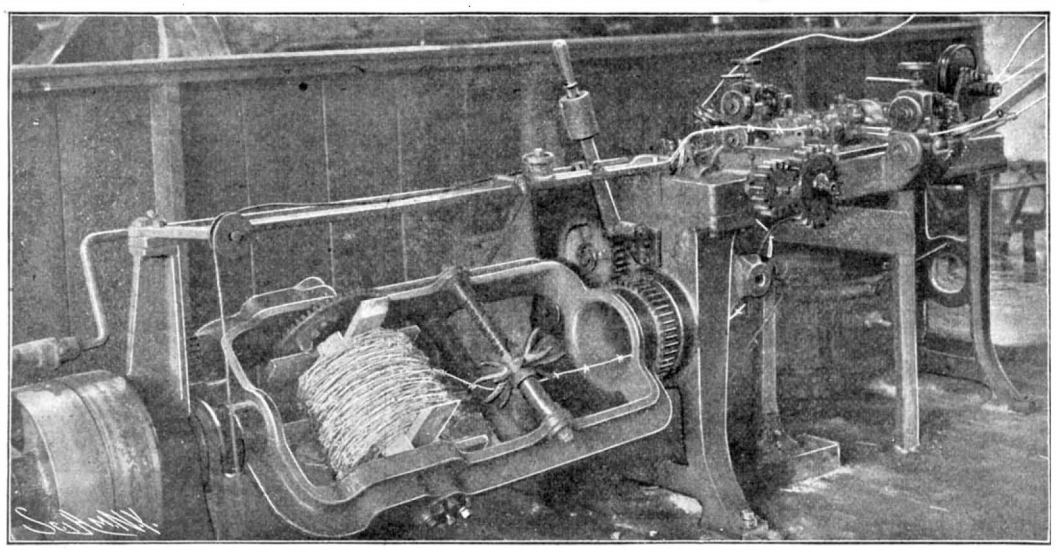
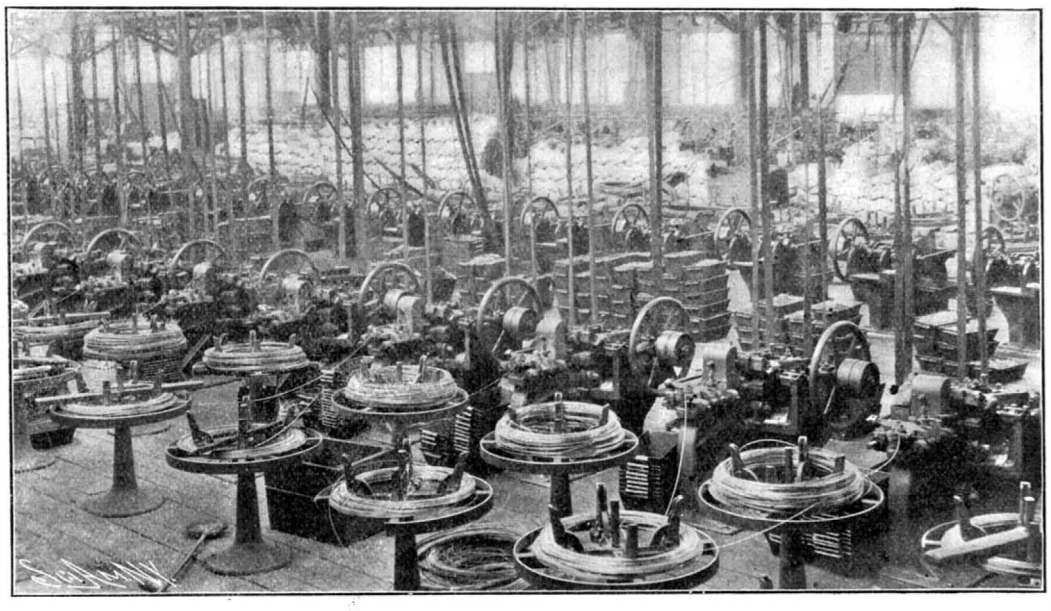


In this department 150 tons of barbed wire are made in a day.

A BARBED-WIRE MACHINE

proceeds to wind up the wire until the whole coil has been drawn down. One of our engravings shows a near view of the process of wire drawing. As the wire drawing is done cold, it can be well understood that with several score of these machines running at the same time, it requires very powerful motive power to drive the mill. After it has been drawn down, it is necessary to remove the strains in the wire, and it is accordingly taken to the annealing room, where it is loaded into the large annealing pots shown in our engraving. After the pot is filled, it is carefully sealed with sand to exclude the air, and the wire is exposed to a steady heat for a period of from eight to nine hours. Of the total product, part is now ready for the open market without any further treatment, a small portion of it is sent to the galvanizing room to be galvanized, and a large proportion of it goes to the nail mill to be made up into wire nails or barbed wire.

NAIL MILL.—In the nail mill there are no less than 150 separate machines, while there is now under construction an additional mill which will contain 150 more machines. As each of these is capable of turning out from 150 to 500 finished nails per minute, it can be well understood that the nail mill is a very busy section of the establishment. A modern nail machine



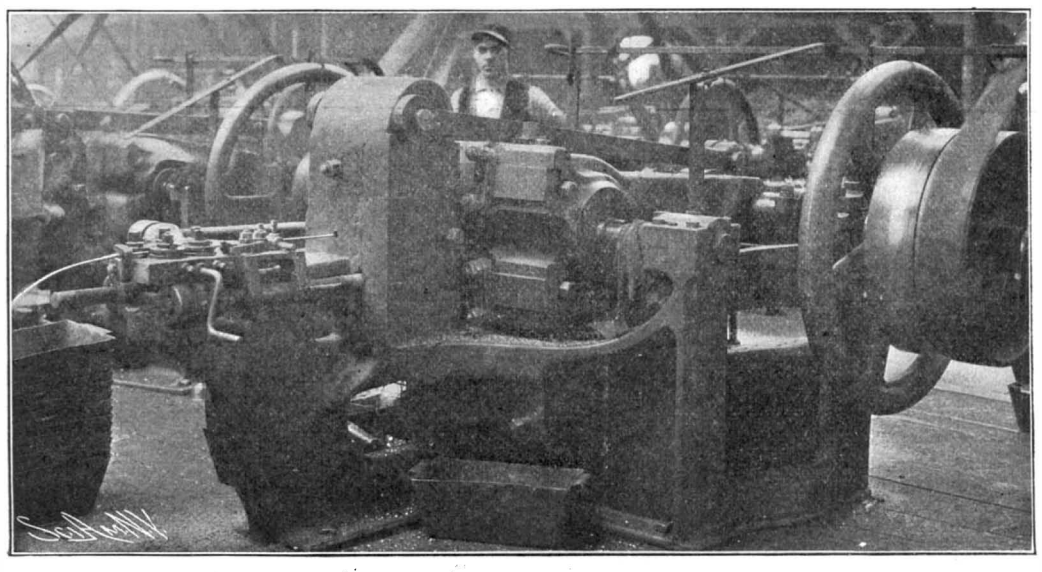
Eight thousand tons of nails are made in this shop per month.

WIRE-NAIL-MAKING DEPARTMENT.

ing what is known as 2-point Glidden barb wire, are placed four coils of wire, carried on reels. The wire from two spools serves to form the strands, and the wire from the other two spools is used for the "barb." The two strand wires, which are heavier than the others, are led between a pair of friction wheels, and drawn to proper tension. They are then met by the two other strands, which are led in transversely, one on either side. At stated intervals of a few inches, according to the spacing of the barbs, a pair of revolving fingers catch the two barb wires and give them a twist around one of the strand wires, and at the conclusion of the twist two pairs of shears cut the ends of the barb diagonally, giving them the desired sharp points. The two wires next pass downwardly around an idler, and then horizontally into a combined winding and twisting frame. The frame itself revolves on a horizontal axis parallel with the machine, and serves by its revolution to twist the two strands. On a shaft arranged transversely within this frame is carried the barbed-wire spool, on which the finished product is wound ready for the market. When it is once started, the operation is continuous and extremely rapid, 150 tons of finished product being turned out in this department daily.

per minute. In this mill 4,000 tons of nails are made in a single month, and when the new addition is completed, the capacity will be increased to 8,000 tons. The boxes of finished nails are covered up and taken to big, revolving iron cylinders, known as rumblers, where they are rolled over and over, the nails being thrown against each other and against the sides of the cylinders and receiving that high polish which characterizes the finished product. The time during which they are treated in the rumblers varies according to the size and quality of the wire. A certain amount of sawdust is also used during this process, in order to clean the nails thoroughly of grease and dirt. The nails are then loaded into 100-pound kegs, stenciled with the size and weight of the nails and the makers' name, and taken to the warehouse, shown in the engraving, in which are stored about 140,000 100-pound kegs, weighing in the aggregate some 7,000 tons.

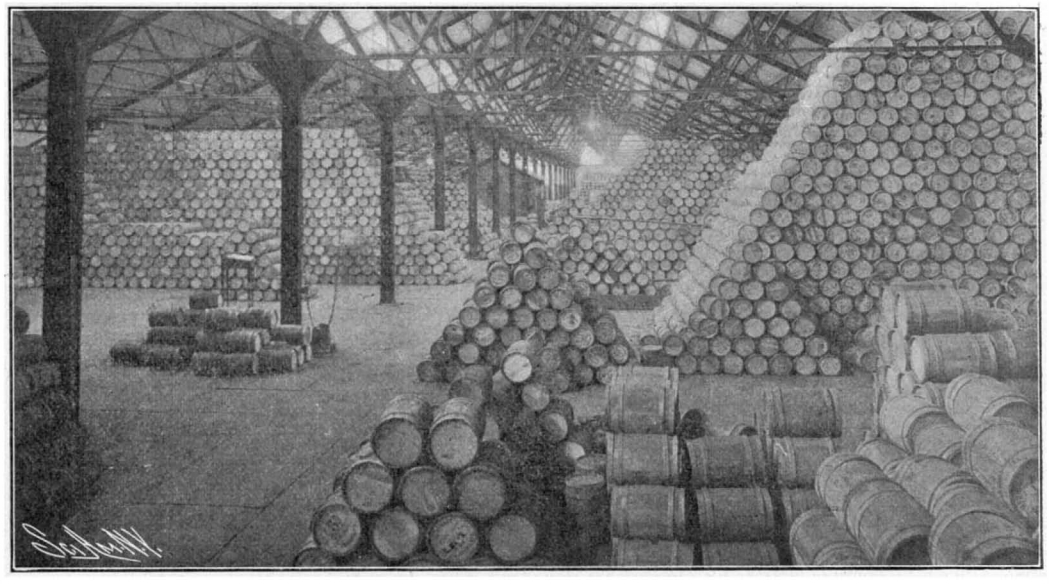
BARBED WIRE.—Another interesting department is the barbed wire shop, in which hundreds of the ingenious machines, shown in our engraving, are in busy operation. Back of this machine, which is engaged in mak-



This machine is making 150 60-D nails per minute; three-penny nails are made at the rate of 500 per minute.

A WIRE-NAIL-MAKING MACHINE.

of the kind with which these shops are filled is one of the best examples of the enormous increase in capacity which has resulted from the introduction of labor-saving machinery. In front of each machine is a reel, upon which the coil of wire is placed. One end of the wire is led into the machine, and as the power is thrown on, one sees the wire disappear through a small hole in the massive vertical casting (see engraving); while to the accompaniment of a rapid succession of blows that sounds for all the world like a Gatling gun in action, a stream of the finished wire nails begins to pour out of the side of the machine into small iron boxes placed to receive them. The wire first passes between two pairs of horizontal, grooved wheels, which are pressed firmly together to give the required tension to the wire as it is drawn into the machine after each finished nail has been formed and cut off. The nail is pointed by the action of a pair of pliers with V-shaped cutting edges, and the head is formed up by the action of a very powerful cam-operated member, which strikes a hammer-like blow. As each nail is finished, the wire is gripped, and enough of it drawn forward to form another nail. The 3-D fine nails are turned out at the rate of 500 per minute, and the large 60-D nails at the rate of 150



The nails are put up in 100-pound kegs; this warehouse has a capacity of 7,000 tons.

WIRE-NAIL STOREHOUSE.

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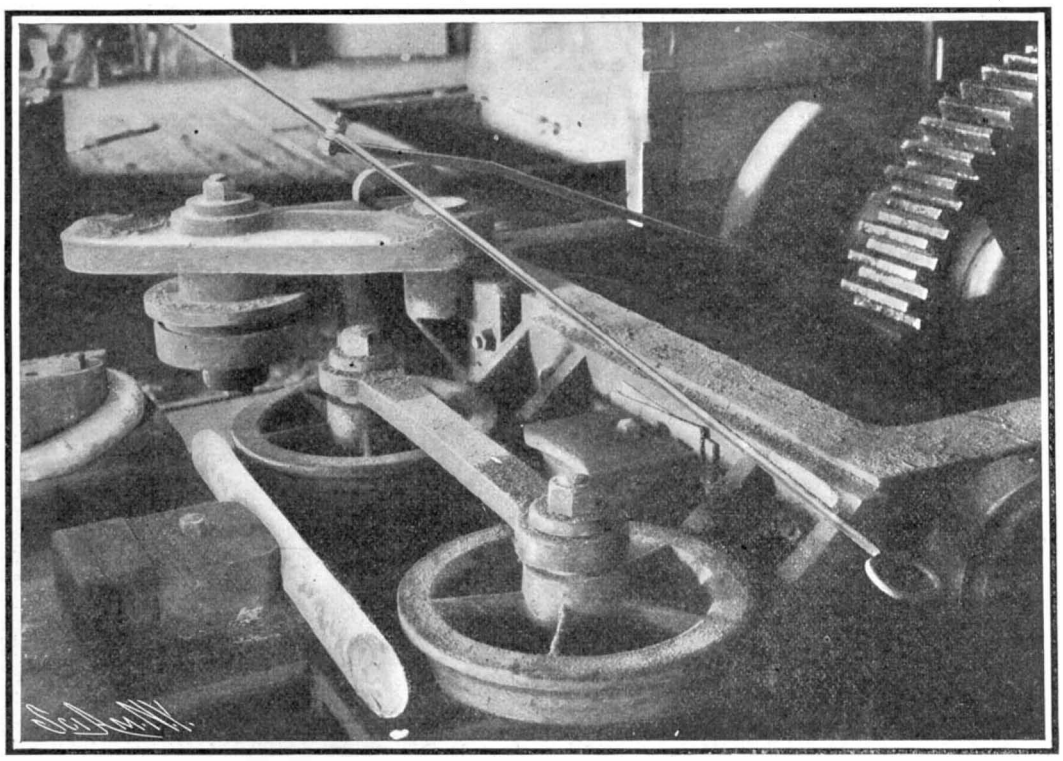
CHAIN MAKING.

In spite of the general supplanting of hand labor by machinery in the various branches of iron and steel manufacture, we meet here and there with an industry in which the skilled mechanic is still able to hold his own, and turn out a product which not the most ingenious machinery can equal, much less supplant. There are not many such cases, it is true, but they exist, and conspicuous among them is the art of chain-making. In the present article, we speak of machine-made cable, it is true; but the term is to be given only a restricted application; for although the links may be cut by one machine, bent into shape in another, and welded under a power-driven hammer, the operation is nevertheless dependent for its success upon the deft skill with which these mechanical tools are manipulated.

The permanence of the traditional methods of chain-making is further suggested by the fact that iron, and not steel, is the material from which it is fabricated. The survival of the older material and the older method in this age of steel and labor-saving machinery is due to the special conditions under which chain is used, and the exacting requirements of its service. A mention of a few of the uses to which chain cable is put impresses one at once with the severity of the service, and the unusual qualities which are required. Thus we find it employed in sling chains in the rough work of quarrying, for lifting heavy weights in building construction, in foundries and machine shops, or at the docks in loading and unloading vessels; while to the lumberman it is absolutely indispensable. In such work the strains are severe and sudden, the links of the chain being subjected to repeated jar and wrench due to the slipping or dropping of the material which is being hauled and lifted. We find it also performing the most important and delicate work of hauling a costly yacht or merchant vessel up a marine railway; while last, and most important of all, is its use as a ship's cable, where, in times of stress, a vessel costing hundreds of thousands of dollars, together with priceless human lives, may depend upon the sound quality of the iron and the fidelity with which the smith has welded the chain, link by link, on his anvil.

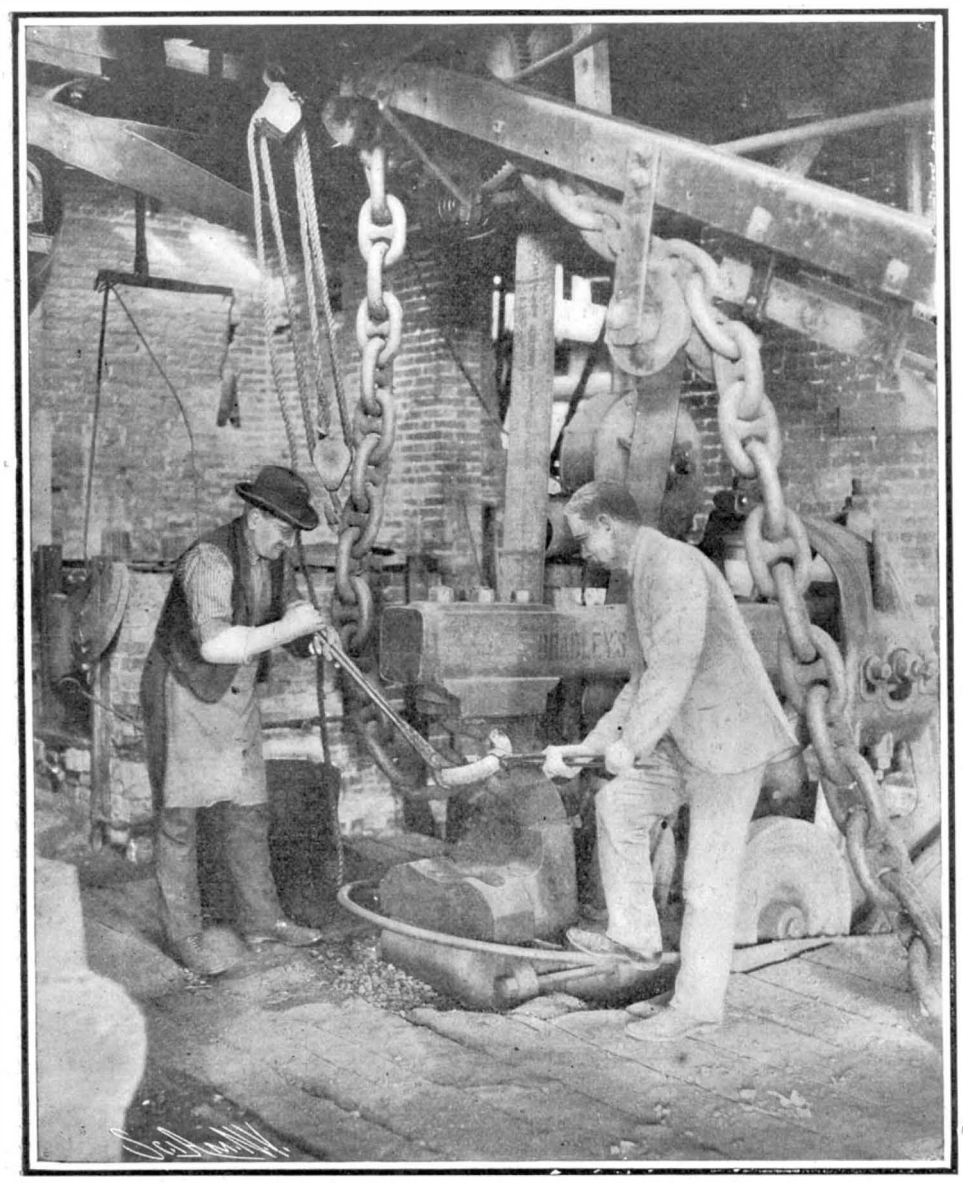
We have chosen for our description of chain making the American Chain Cable Works, of Troy, New York, largely for the reason that in this establishment are made large quantities of ships' cables for the United States government, and particularly for the lightships of the United States lighthouse service.



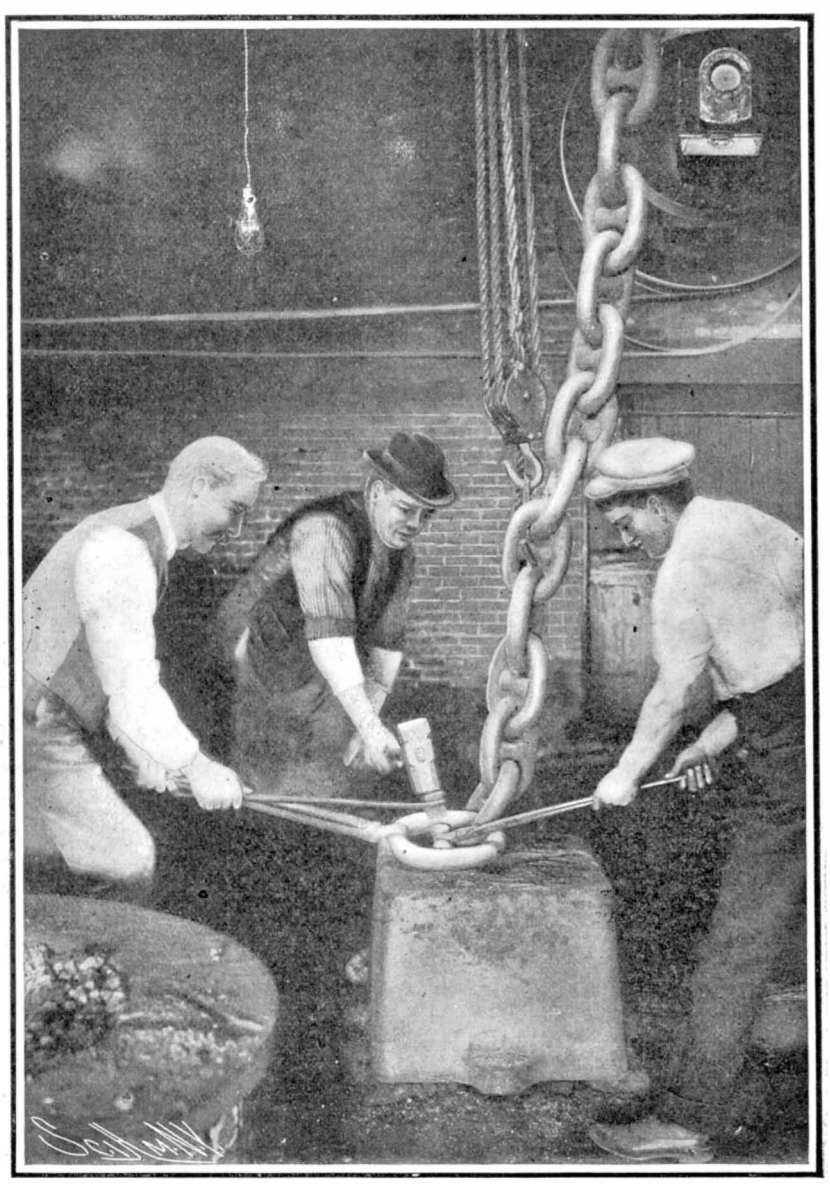
Hydraulic Machine for Forming the Links.

QUALITY OF IRON FOR CHAIN MAKING.—The iron used is a specially rolled grade, of high tensile strength and great ductility, the object being to secure a chain which, on the application of a sudden stress—as, for instance, when a ship is riding at anchor in a heavy seaway—will stretch and so resist the strain gradually, instead of snapping, as would be liable to happen with material of higher tensile strength but small ductility or power of elongation. Chain of from 5-16 inch up to 2 inches diameter is forged by hand, and above 2 inches it is forged with the assistance of machinery.

HAND-MADE CHAIN.—In the smaller sizes the whole operation of chain making is done by a single smith without any helper. The length of completed chain is hung upon a hook or some convenient support near the anvil, and the operation of forging the link proceeds as follows: In his fire the smith will have two or three short rods of the required diameter, and as one is heated to, say, a cherry red, he withdraws it, cuts off the desired length for one link, gives it a couple of blows to form the welding scarf, bends it through say about 130 degrees, hooks it into the end of the completed chain, and brings the ends together for welding. He then raises the link to a welding heat in his fire, places the abutting ends over what is known as the bick-iron, gives it a few taps to insure a good weld, brings over a "dolly" (which is hinged at the outer end of his anvil and when brought over registers above the bick-iron), and with half a dozen blows on the dolly, accompanied with a dexterous movement of the link, the weld is completed and the link smoothed up to a neat finish. The rapidity with which the smiths do this work is very remarkable. Thus, in the case of a 7-16-inch chain, with thirty links to the yard, an expert smith will cut off from the iron bar, scarf, bend up into shape, and weld the links, at the rate of 18 yards in a day of nine working hours, which is two yards per hour, or one link per minute. We present an illustration showing a smith and his two helpers (it takes three men to hand-forge the larger chains) forging a 1¼-inch ship cable. The iron is cut to about one-foot lengths, and several of these are being heated in the fire at the same time. The operation is as follows, the various steps succeeding each other with great rapidity: First, the helper to the right of the anvil withdraws the heated piece, drops one end into an eye at the end of the anvil, and bearing down upon the tongs, bends the piece over to an angle of about 45 degrees. The smith then takes it in his tongs, and with a few taps of the sledge it is bent around as shown in our illustration. It is heated again, passed through the end of the chain by the smith, laid flat on the anvil and the welding scarfs are put on with a few



Bringing Scarfed Ends of Link Together Ready for Welding.



Inserting the Stud in Heavy Stud Chain.

MANUFACTURE OF HEAVY MACHINE-MADE CABLE.

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blows of the sledge. The link is now raised to a welding heat, welded by a few blows by the helpers, laid over the bick-iron (which will be noticed in our engraving projecting from the anvil toward the smith), the hinged dolly is brought over, and a few rapid blows on the dolly, while the smith turns the link to and fro, serve to bring the weld up to a smooth finish. The link is now laid on edge; a single blow from the sledge brings it into shape, and with a final tap or two of the smith's hammer the link is finished. At this forge as many as thirty-five links will be added to a heavy chain of this size in one hour, or say about one every two minutes.

Machine-Made Chain.—In the heavier sizes of chain of over 2 inches diameter, it becomes necessary to call in the aid of machinery in shearing the iron into lengths for the links and in bending the links into shape. The scarfs are produced by shearing the iron at an angle of 60 degrees with the axis of the bar, all cuts being taken with the inclination in the same direction, so that when the links are formed up the scarfs will lap in the desired relative position. The iron is then heated and placed in a hydraulic bending machine, where it is formed against a block into a rough U-shape at the first stroke, and then rolled into the oval link form on another block adjoining the first. These operations are shown in the accompanying engraving. The scarfed ends are left wide enough apart to allow of the link being hooked onto the end of the chain which is being forged. The scarfed ends are now brought down snugly into contact under an automatic quick-acting hammer, and the link is heated and then welded up under the same hammer. Most of the ship cable has a cast-iron stud inserted in each link. The ends of the stud are hollow, to match the round of the chain, and when the link has been hammered down snugly into place, it is impossible for the stud to be displaced. Indeed, the pull upon the cable, by tending to straighten it out, causes the link to tighten upon the stud and hold it the more securely in place. Cables are made in standard lengths of 15 fathoms or 90 feet, and any greater length is obtained by shackling several of the 15-fathom lengths together, the average length of a ship's cable being about 90 fathoms, or 540 feet. The life of such a cable is about ten years. This, however, depends upon the judgment of the insurance company.

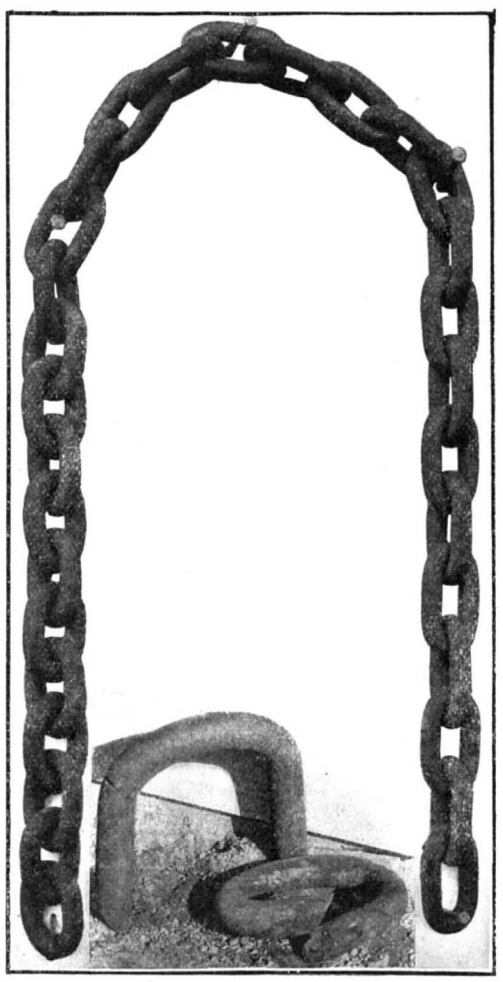
Testing.—In the case of all cables built for government lightships, one shackle and one swivel are tested to destruction, as are also two sample pieces of the chain, each five links in length. The peculiarly ductile qualities of the Burden iron from which most of the chain at this works is manufactured, is shown in the accompanying illustration, where the right-hand portion of the chain, including ten links, stretched without fracture until the ten links were equal in length to twelve links of the untested chain.

Blacking.—When the 15-fathom length is completed, it is placed in an iron box and heated by steam, and then drawn through a vat of boiling tar, known as the "tar kettle." Here it receives a thorough coating, after which it is drawn out upon an iron grating, where the surplus tar is allowed to drain off, leaving a heavy protective coat upon the cable.

In conclusion it should be noted that although each link of a chain consists of two thicknesses of bar, it must not be presumed that a chain possesses double the strength of a single bar; actually there is a reduction of three-tenths in the strength due to the formation into links, so that the chain has but about seven-tenths of the united strength of two bars of the same diameter of iron. Moreover, as the strength per square inch of a heavy bar is not so great as that of a smaller diameter iron, there is further reduction to be made on this account. Thus, if a bar of ordinary rolled iron shows a breaking strength of twenty tons per square inch, the breaking strength will decrease to 19 tons up to 2 inches, and 18 tons per inch up to 3 inches diameter of rod. Consequently, the breaking strength of chain made of 1-inch iron will be about 50,000 pounds, and the breaking strength of 2-inch chain about 190,000 pounds.

Slag Portland Cement.

The American consul-general at Coburg, Germany, reports: Portland cement has been made from blast furnace slag for several years in various cement works in Germany, Luxemburg, and Belgium, and has yielded very satisfactory results, especially in regard to quality. Negotiations are being carried on with some blast-furnace works with a view to the introduction of the slag-cement industry into England, Austria, and France. In some respects a blast works has a considerable advantage over other Portland cement factories because the motive power from the cement works can be supplied by a blast-furnace gas motor with electric transmission, the rubber or waste coke from the blast furnaces can be utilized in the cement kiln, and the principal raw materials—namely, the granulated slag and the limestone—are close at hand. Besides, there are other minor advantages. Portland slag cement has also some advantages over natural Portland cement; for while the yield from the raw materials when the former is used is about eighty per cent, the yield when the ordinary raw materials are used is seldom more than sixty per cent. As the cost of production per ton of raw materials is nearly equal in both cases, a saving of about twenty per cent in fuel, labor, etc., is effected in the case of slag cement. Besides, this Portland slag cement is more trustworthy and more regular, and its manufacture can be more easily controlled than that of the so-called natural Portland cement, because the raw material—namely, the blast-furnace slag—is, as a rule, a regular product whose chemical composition is easily controlled; consequently, any alterations which are liable to take place are known beforehand, and precautions can accordingly be taken in time. This is not the case when the natural raw materials are used. Some recent tests with Portland cement from blast-furnace slag, made in the municipal laboratory at Vienna, showed that mortar composed of three parts of sand with one part of this cement gave the following results: 1. After seven days' hardening—Tensile strength, 383 pounds per square inch; strength of compression, 3,880 pounds per square inch. 2. After twenty-eight days' hardening—Tensile strength, 551 pounds per square inch; strength of compression, 5,411 pounds per square inch.



The ten links to the right stretched to the extent of two links in ten without fracture. Of the two detached links, the fractured one, a piece of commercial iron, failed in a bend of 90 degrees; the other, of special Burden iron, was bent as shown, without fracture.

THE ACTION OF CHAIN IRON UNDER TEST.

This smith and his two helpers are forging 1¼-inch ship's cable at the rate of 35 links in one hour.

THE MANUFACTURE OF CABLE BY HAND.

Both masonry and concrete are occasionally employed in American mines, but are more common in Europe. It has been found that concrete is often advisable at the collar of shafts, either inclined or vertical. Steel is also used in mine support to a limited extent. In shafts it might be employed to advantage, and would prove a perfect protection against fire. Under heavy pressure steel would probably prove a dangerous substitute for timber, as it would give little warning of collapse; and if it gave way under the strain, accident would come without warning, whereas in workings supported by timbers there is always sufficient indication of approaching disaster—sufficient in most cases for men to escape, if not to prevent collapse. Filling is the only safe course to pursue, as no timber will support heavy ground perpetually.—Mining and Scientific Press.

The term "limestone dike" is a misnomer. Dikes are intrusive—injected in molten condition from below. Sedimentary beds, such as limestone, quartzite, sandstone, shale, etc., are not dikes. These latter are sometimes called reefs. Eruptive rocks are also intruded in flat sheets in horizontal formations. These are called sills. Should the formation be uplifted subsequently these sills might be mistaken for dikes, or dikes thrust upward into rock strata standing at a high angle might be mistaken for sills if earth movements caused the inclosing formation to assume a recumbent position. In studying the stratigraphy of rock masses, care must be taken not to mistake slaty cleavage for lines of sedimentation. The former is induced by pressure and movement, the latter by deposition of the rock material in water. Cleavage planes and lines of sedimentation may coincide.—Mining and Scientific Press.

What is believed to be the first iron casting made in the territory now included in the United States, is preserved in Lynn, Mass. Its history is well authenticated. It is a cooking-pot, weighing a little over two pounds. It was made about 1642, near Lynn, where a small blast furnace was built in that year. This furnace used charcoal for fuel, with bog ore found in the meadows along the Saugus River, and oyster-shells as flux. The furnace was operated until 1688, with some intermissions.

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"YOUNG AMERICA"—A NAUTICAL PREPARATORY SCHOOL.

The accompanying view of the handsome three-masted auxiliary ship "Young America" represents a promising attempt to solve the serious problem of giving the youths of this country a comprehensive education under circumstances which will insure strict discipline, the best of hygienic surroundings, and an opportunity to obtain that personal knowledge of places and people which more than anything else serves to round off and complete an education. The Nautical Preparatory School, as it is called, was incorporated not long ago under the laws of the State of Rhode Island, and in accordance with the purpose of the school the full-rigged auxiliary ship "Young America" is now nearing completion at Perth Amboy, N. J., under the plans of its designer, William E. Winant, of this city, to whom we are indebted for the drawing from which our illustration is made.

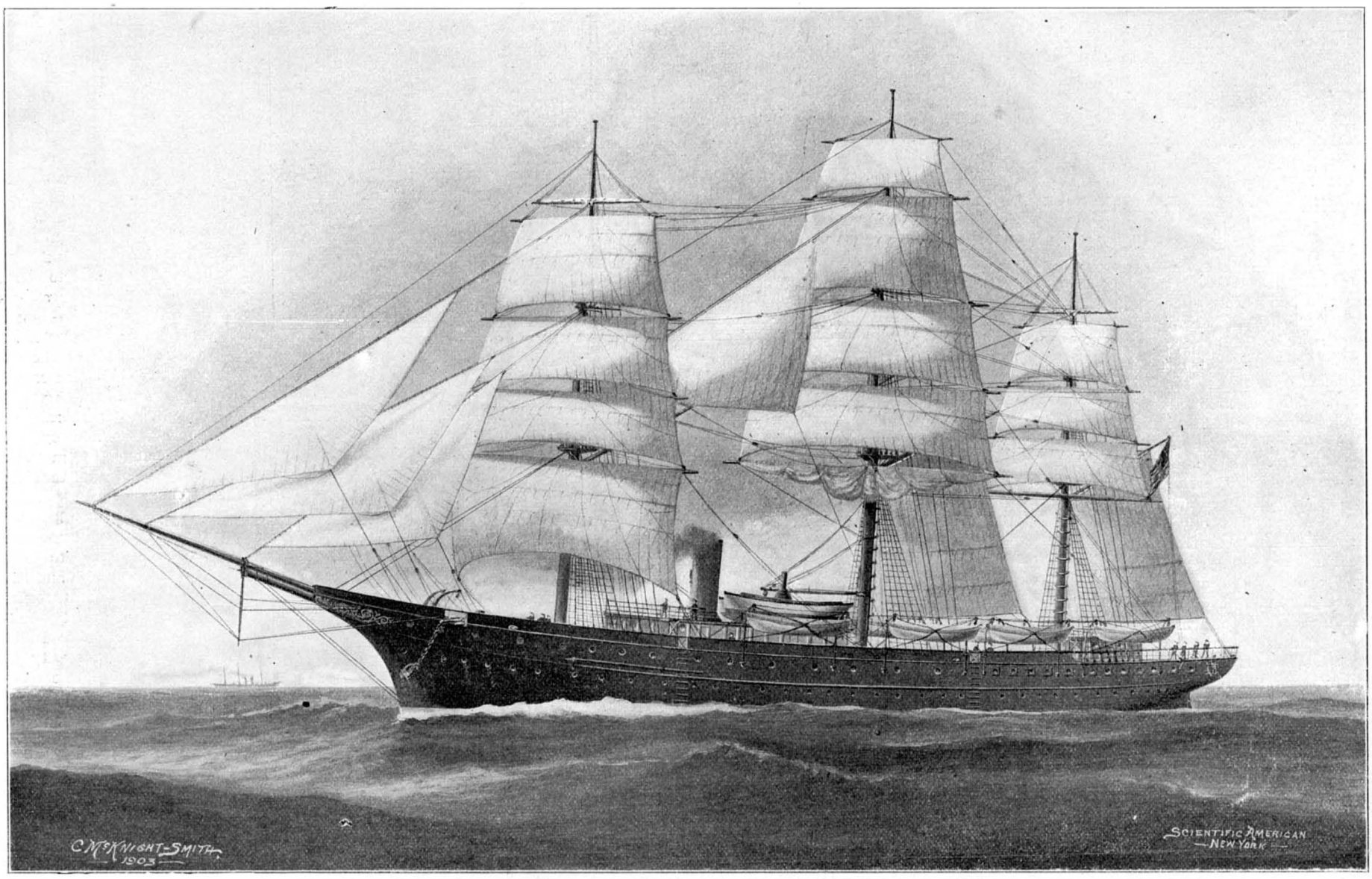
"Young America" is, strictly speaking, a floating school, in which, in addition to the regular curriculum which is taught at any first-class preparatory school, the pupils will have an opportunity to become instructed in those arts and sciences which go to the making of an efficient naval officer. Of course, the prime object of the school is to prepare boys either for universities, or for the various professions, or for commercial business. At the same time the routine life on the ship will be similar to that on the regular training ships of the navy, and the boys will acquire all the benefits of the strict discipline which has made the military schools so popular in this country. They will also be afforded a magnificent opportunity for coming in touch with the great outside world. Each of the four years "Young America" will start on an extended cruise, during which she will touch at various ports, where the boys will be given an opportunity to go ashore under the care of their instructors, and visit the buildings, institutions, and historic points of interest and receive suitable instruction, historical, ethnological, commercial, etc., relating to the particular cities and districts that may be visited. Thus the cruise of the first year of eight months will cover no less than 16,000 miles; in the second year of eight and a half months, the cruise will cover 24,000 miles; in the third year of ten months 26,000 miles will be covered, and in the fourth and last year 27,000 miles; so that in the four years of the course, the boys will travel nearly 100,000 miles, and will have visited all the principal ports of the world.

"Young America" is built of steel, and will accommodate with comfort 250 cadets, besides a faculty of 25 instructors and a working ship's company capable of taking care of the craft in all conditions of weather. As a matter of fact, she will be twice as large as the United States Naval Academy training ship "Chesapeake," and will be greatly superior to her in her many facilities. The ship is 282 feet in length over all, 230 feet on the water line, and she has a beam of 44 feet and a draft of 18 feet 6 inches. On this draft her displacement is 2,600 tons. Her total spread of canvas is 21,000 square feet, and she is capable of making under steam a speed of 8 knots an hour. Ordinarily the vessel will be under sail, and the engine will only be used in calms, or when it may be necessary to hasten the voyage. Electric light will be used throughout, and especial attention has been paid to artificial ventilation, which must be used when stress of weather makes it necessary to close the air ports in the living spaces. Although the greater number of the cadets will sleep in hammocks, there are stateroom accommodations for thirty of the cadets, these being assigned to the cadet officers of the battalion as a reward for proficiency in scholastic work. The berth deck will contain the quarters for the academic staff and the berthing and stateroom accommodations for half of the cadets, besides the living space for the crew. Forward on the main deck will be the galleys, bakery, laundry, and the refrigerating plants. Extra berthing space has been allowed for each cadet's hammock, and he has his own private locker.

The greatest interest attaches to the school deck, on the after third of which are the captain's, the executive officers', the doctors' and the head of the academic departments' cabins, together with a commodious sick bay and dispensary. The midship portion of the school deck is given over to the berthing in hammocks of the remaining half of the cadets and for the united mess of the whole battalion. For this purpose there will be twenty-three portable tables, at which the boys will sit in squads of ten and twelve; and during the hours of study in the early evening, canvas covers will be put over these tables, and under electric lights the recitations will be prepared for the following day. A large space forward of the messroom will be used for all recitation purposes. Then follows a large room, which is to be used as a museum, in which specimens gathered from the sea and from various parts of the world visited will be collected and arranged. Forward of this are lavatories and baths, while in the cabin aft on the berth deck is a large library. On the main deck abaft the smokestack is a music and recreation room. "Young America" carries for safety and for the purpose of drill and exercise eight 28-foot New Bedford whaleboats, two 36-foot steel cutters, and two large 36-foot sailing cutters, in which the cadets will be made familiar with boat handling.

The deck officers will be appointed monthly according to merit. The cadet captain, executive, and navigator will be chosen from the senior class, the cadet lieutenants from the two upper classes, and the midshipmen from the third class. In addition to boat handling, all the cadets will be taught to hand, reef, and steer. They will have no manual work to do except sail and spar drills, and this in the way of gymnastic exercise.

A promising feature of the scheme is that as many of the ship's officers as possible will be either regular officers of the navy or men who have been graduated from the United States Naval Academy, and the discipline of the ship will be in accordance with service regulations.



THE FLOATING SCHOOLSHIP "YOUNG AMERICA."

A private school in which during a four years course the students will cruise for 100,000 miles and visit every leading port and country in the world.

Trial Trip in New York's Subway.

Cars were running during the week of November 22 in the new subway of New York. The road was not open to the public, but was simply tested. Two of the storage battery cars used on the 34th Street cross-town line were borrowed for the experiment. One car was sent into the tunnel at Canal Street, and run back and forth over the line as far back as Thirty-fourth Street. Another car was run from Fiftieth Street up to the end of the finished line in upper Broadway.

Rescue of Nordenskjold.

The Argentine warship "Uruguat" arrived November 23 at Rio Gallejio with the members of the Nordenskjold Antarctic expedition on board. The party was rescued on Seymour Island and Louis Philippe Island. The French expedition which set out to relieve Nordenskjold will proceed on its journey and engage in scientific work.

Dr. Nordenskjold, before he set out on his ill-starred expedition in the "Antarctic," had achieved fame as an explorer of Tierra del Fuego and as an Alaskan traveler. The "Antarctic" left Gottenburg October 8, 1901. Nordenskjold touched at Falmouth, England, and at Buenos Ayres, December 16. The "Antarctic" sank in Erebus and Terror Gulf, which it entered in January, 1902. On January 15 he landed on Paulet Island, where he was compelled to make his camp while waiting the coming of a rescuing expedition. The last stretch of the journey to the south was begun December 21, and terminated in the destruction of the ship in February.

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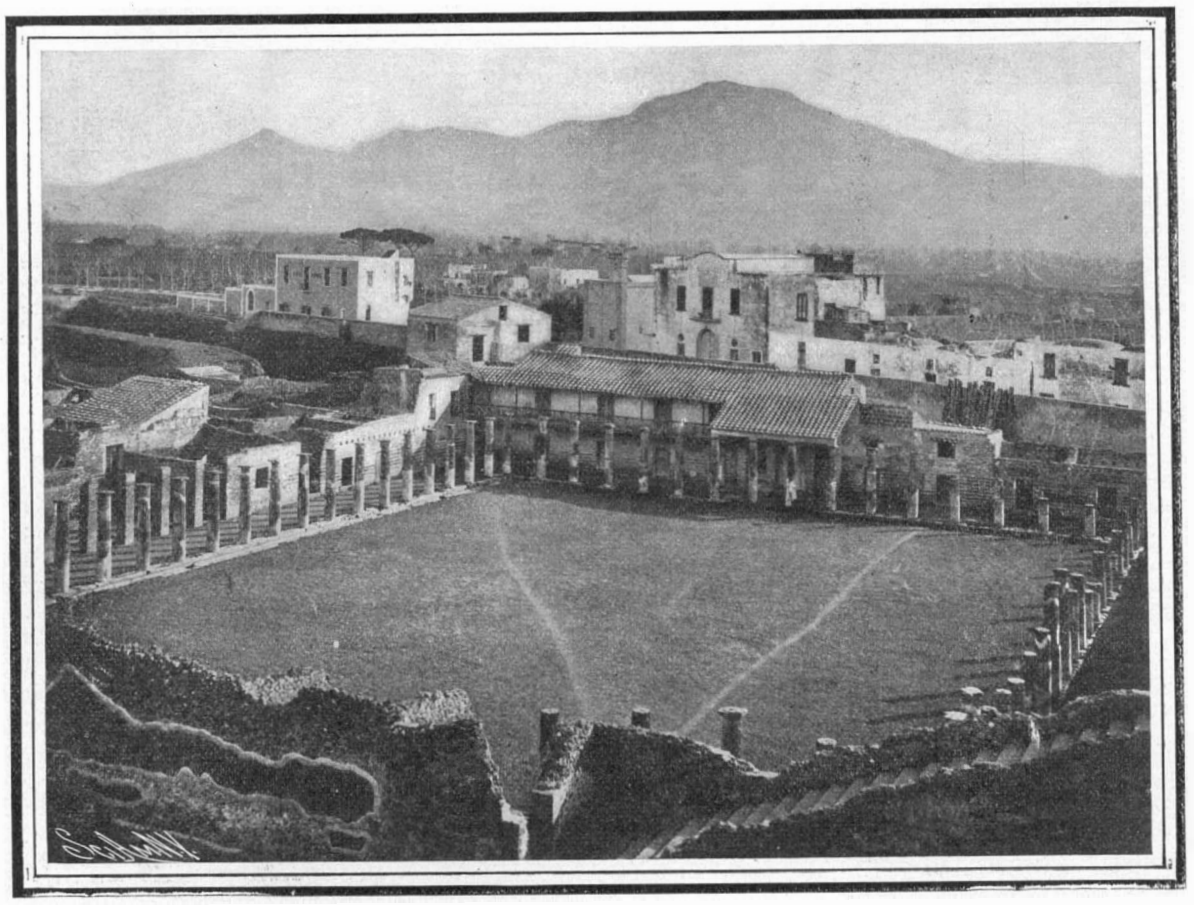
POMPEIIAN GLADIATORIAL ARMS.

A number of the handsomely decorated gladiators' arms which have been found at Pompeii and the neighboring localities are here illustrated, also the locality in which many of them were discovered at Pompeii. Most of them are of bronze, and one is inlaid with silver. One of the gladiator's helmets shown is the most elaborate of the series. It is ornamented with repoussé figures in high relief, representing episodes of the siege of Troy. Owing to its rich decoration it is natural to suppose that it was intended as a prize in the gladiatorial combats rather than to stand actual service. The gratings which protected the eyes can be raised up, as they are hinged at the top. At the bottom they are held down by a catch. In some forms of helmet these pieces are round and of much smaller size.

Two highly-ornamented greaves are also illustrated. These, however, do not belong to a set. That on the right is the greave for the left leg. In the center is a high relief representing Minerva in a standing position with spear and shield. On either side is a Cupid, separated from the center by an ornamental band. The specimen on the left, which is not so well preserved, has the figure of a gladiator as the principal ornament. In the center is the upper part of a helmet, of which the lower part has disappeared. Its relief pattern shows a more primitive workmanship than the others. The other handsome specimens illustrated are highly ornamented in relief designs. The round shield in the center carries a Medusa's head encircled by two wreaths of olive. The ornaments of this shield are inlaid with silver. Although the unusual weight and rich ornamentation of these arms lead one to suppose that they were not made to be actually worn, Sir William Hamilton, who was present during the excavation, stated that he observed the linings of the helmets and greaves, which have now disappeared, and he thinks they were actually intended for wear.

Some of these arms were found in a building or large inclosure whose exact purpose has been the object of considerable discussion. It is commonly known as the Gladiators' Barracks, for the reason that many such arms were found there, and also the arrangement of the building seems to show that it was used for soldiers' or gladiators' quarters. The engraving clearly shows the large rectangular inclosure, which measures 183 feet long by 148 feet wide. It is surrounded on all four sides by a colonnade whose columns are painted red at the lower part, and alternately red and yellow at the upper. The wall back of the columns is covered with stucco. Different gladiators' arms like those already discovered were found here, but no soldiers' arms, which leads to the supposition that the building was occupied by the gladiators exclusively. Inscriptions which are scratched on the wall also refer to such combats, and in one place is to be seen a drawing of a gladiator in fighting position with the inscription XX Valerius. Back of the columns the central space was surrounded by a series of cell-like rooms one over the other. A gallery around the building gave access to the upper set. These chambers may have accommodated the gladiators, but to have so many of them (there were at least 66 rooms) the number of gladiators at Pompeii must have been very large. The lower rooms are in a rather good state of preservation, but the upper ones have fallen down. In one corner will be observed part of the series which has been restored and which gives a good idea of what the building was like.



THE GLADIATORS' BARRACKS AT POMPEII.

GLADIATORIAL ACCOUTERMENTS.

Turpentine Industry.

The discovery of a new way of extracting turpentine, made two years ago by Dr. Charles H. Herty, working under the direction of the Bureau of Forestry, is resulting in a complete change of methods by turpentine operators all over the South.

In a bulletin published last spring by the Bureau of Forestry the claim was made that the experiments with the new cup and gutter system of turpentining had resulted in an increase over the old boxing system of 23 per cent in the amount of the product extracted. This figure has now been raised to more than 36 per cent. In other words, Dr. Herty's system, when universally adopted in the South, as it is bound to be sooner or later, will have raised the turpentine production of this country by more than a third, provided the same number of trees are used. Two years ago when Dr. Herty first made known his discoveries he put 20,000 cups into operation. Last year this figure was increased to about 400,000. This year a conservative estimate places the number of cups to be used at 3,000,000. The figures give some indication of the rapidity with which turpentine operators are adopting the new system. The change of methods has been so rapid that the pottery company which undertook to supply operators with earthen cups has been unable to keep up with its orders and has been obliged to refuse contracts for over two million cups. It is safe to say that the majority of the large turpentine operators in this country have given up the boxing system and will extract their turpentine by means of cups and gutters.

The economic saving of this new discovery is enormous. It not only causes a great increase in the amount of turpentine produced, but it is a most important factor in saving the pine forests of the South. Every one knows that trees from which turpentine has been extracted by the old method—"boxed" timber it is called—soon die from the wounds inflicted on them. The cup and gutter system, on the other hand, is not fatal to the life of the tree, and does very little damage to the timber.

The Bureau of Forestry has arranged to give the personal assistance of Dr. Herty to turpentine operators who desire to install the new system.

The recent annual report presented to the shareholders of the De Beers Consolidated Mines shows that last year $26,205,869 worth of diamonds were mined at Kimberley, South Africa, on which the profit was $11,511,490.

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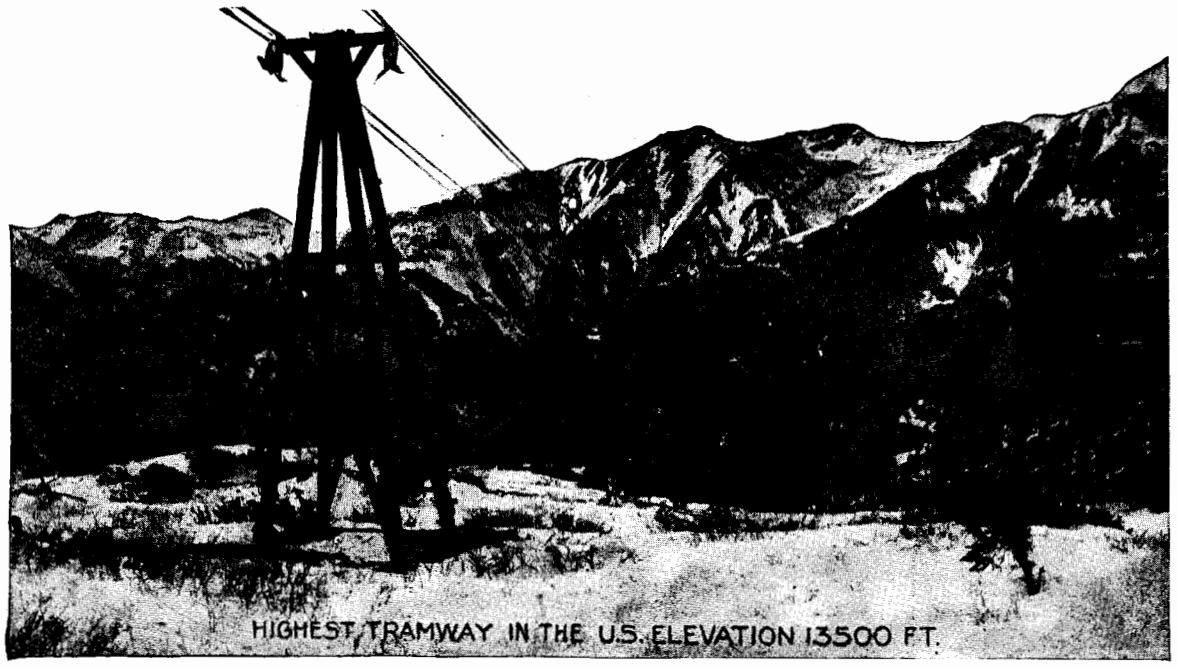

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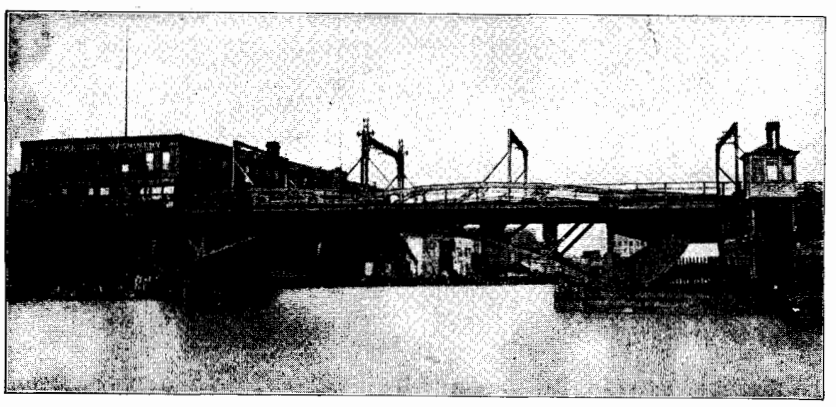

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THE LAYSAN ALBATROSS AND ITS DANCE.*

BY WALTER K. FISHER.

With many ornithologists the word Laysan is so intimately connected with pictures of albatrosses that the two have become inseparably associated. Surely no birds can stand out more vividly in our memory than these splendid creatures, not alone on account of their great numbers and remarkable appearance, but more perhaps from the unusual charm and interest which attaches to their personalities. Their large size and striking plumage at once raise them to an exalted place among all sea birds, a position similar to that which tradition and fancy have accorded the eagle among birds of the land.

The Laysan albatross or gony is distributed all over the island, with the single exception of the beaches, which on all sides except the west are colonized by the black-footed albatross. The flat plain surrounding the lagoon is their favorite habitat, and I found the young here in far the greatest numbers. There seems scarcely a tussock of the grass which covers the greater portion of the slopes of the island but has an ungainly young bird in its shadow ready to snap at the intruder with a show of ferocity. These amusing creatures sit on their heels with the whole length of the tarsus on the ground or tilted slightly in the air, as shown in the illustration. Their spare time is spent in gazing stupidly around, but if their reverie is at all disturbed by one passing too near they fly into an apparent rage, lean forward and snap their beaks viciously, or sway their uncouth bodies from side to side in a frantic attempt to maintain a balance.

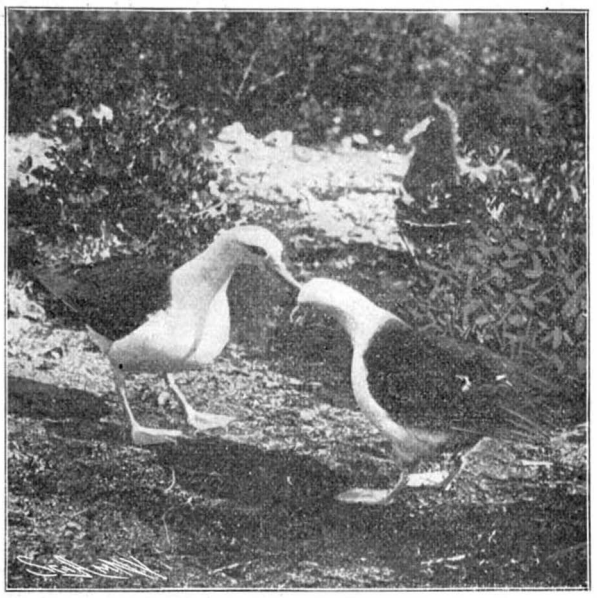
Usually, after the first paroxysm of snapping is over, one can stroke them with little danger of scratched hands. They maintain a small fire of objection, with impotent nips, or try to sidle off. The old birds, however, are quite different, and do not seem to mind the presence of man. One can walk among them without disturbing their various occupations and amusements in the least. Only when suddenly startled do they exhibit any tendency to snap their bills, and then they are easily calmed. They back away from any proffered familiarity with great rapidity, unless suddenly hindered by a tuft of grass, which event surprises them immoderately. They will not allow themselves to be handled, and make off at a great rate if one offers them this indignity. They have a half-doubting inquisitiveness which leads them sometimes to walk up to the visitor and examine anything conspicuous about his person. One bird became greatly interested in the bright aluminium cap to my tripod, and strolled up and examined it carefully with both eye and beak, appearing somewhat astonished when the cap tinkled.

When standing beside their young they present a very attractive sight, as their plumage is always immaculately clean. The region about the eye is dark-grayish, overhung by a pure white eyebrow, which gives them a decidedly pensive appearance. They have an innate objection to idleness, and consequently seldom stand around doing nothing, but spend much time in a curious performance, the meaning of which I am at a loss to explain. It has been called courting, but as the antics are carried on during the birds' residence of about ten months on the island, they are probably an amusement, in which the albatrosses indulge immoderately in lieu of other diversion. This game, or whatever one may wish to call it, may have originated in past time during the courting period, but it certainly has long since lost any such significance.

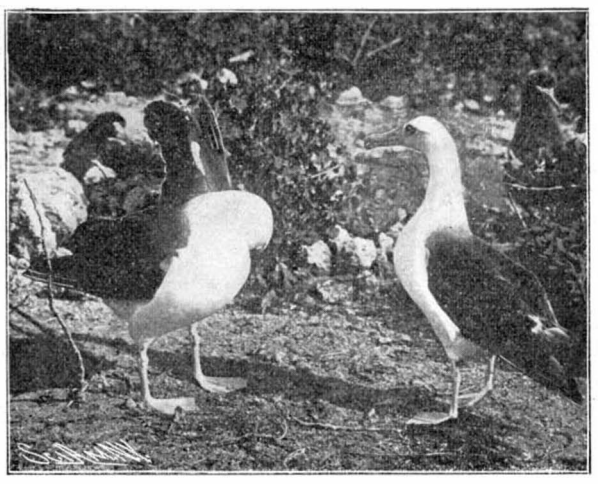
The proceeding in brief is as follows: Two albatrosses approach each other bowing profoundly and stepping rather heavily. They circle around each other nodding solemnly all the time. Next they fence a little, crossing bills and whetting them together, pecking meanwhile, and dropping stiff little bows. Suddenly one lifts its closed wing and nibbles at the feathers underneath, or, rarely, if in a hurry, merely turns its head and tucks its bill under its wing. The other bird during this short performance assumes a statuesque pose and either looks mechanically from side to side or snaps its bill loudly a few times. Then the first bird bows once and, pointing its head and beak straight upward, rises on its toes, puffs out its breast, and utters a prolonged nasal groan, the other bird snapping its bill loudly and rapidly at the same time.

Sometimes both birds raise their heads in air and either one or both utter the indescribable and ridiculous bovine groan. When they have finished, they begin bowing at each other again, almost always rapidly and alternately, and presently repeat the performance, the birds reversing their rôle in the game, or not. There is no hard and fast order to these antics, which the seamen of the "Albatross" rather aptly called a "cake walk," but many variations occur. The majority of cases, however, follow the sequence I have indicated. Sometimes three engage in the play, one dividing its attention between two. They are always most polite, never losing their temper or offering any violence. The whole affair partakes of the nature of a snappy drill, and is more or less mechanical.

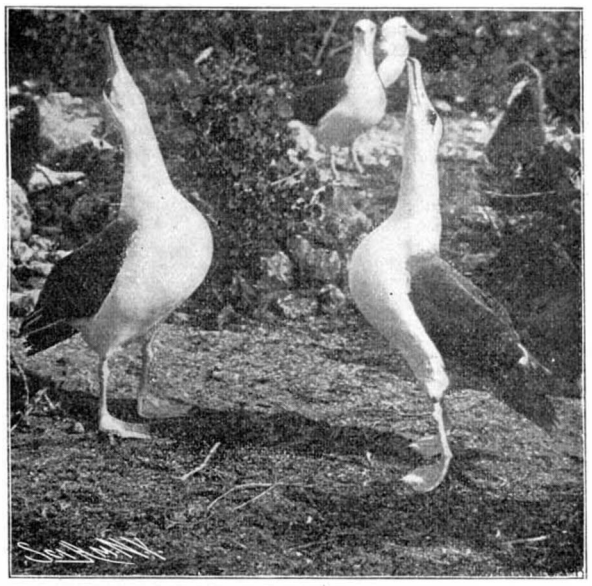
Occasionally one will lightly pick up a twig or grass straw and present it to the other. This one does not accept the gift, however, but thereupon returns the compliment, when straws are promptly dropped and all hands begin bowing and walking about as if their very lives depended upon it. If one stands where albatrosses are reasonably abundant, he can see as many as twenty couples hard at work bowing and groaning on all sides, and paying not the slightest attention to his presence. When walking through the grassy portions of the island, I have seen white heads bobbing up and down above the green, as solitary pairs were amusing themselves away from the larger congregations of their kind. If I walked up to them, they would stop and gaze in a deprecating way, and walk off, bowing still, with one eye in my direction. Having reached what they considered a respectful distance, they would fall to and resume their play.



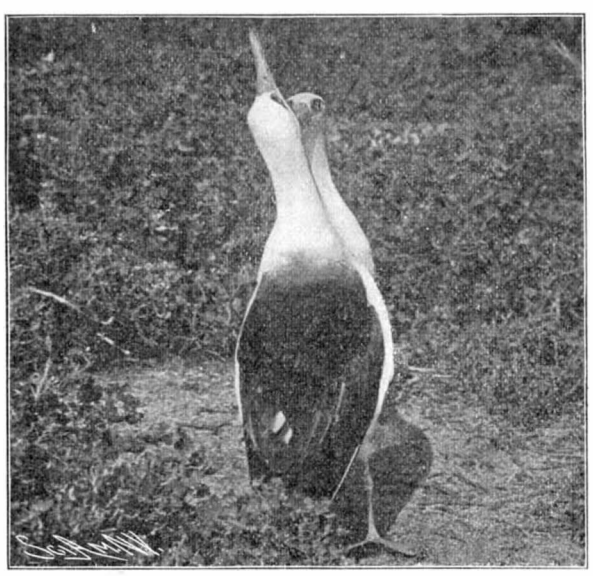
The First Step in the Dance.



The Second Step in the Dance.



Finale of Dance—The Duet.



A More Common Ending of the Dance—One Bird "Singing," the Other Snapping Its Beak.

THE ALBATROSS "DANCE."

Should one enter a group of albatrosses which have been recently engaged in this diversion and begin to bow very low, the birds will sometimes walk around in a puzzled sort of way, bowing in return, a curious fact, which F. H. von Kittlitz recorded as early as 1834:

"When Herr Isenbeck met one, he used to bow to it, and the albatrosses were polite enough to answer, bowing and cackling. This could easily be regarded as a fairy tale; but considering that these birds, which did not even fly away when approached, had no reason to change their customs, it seems quite natural."*

One moonlight night we strolled over the island after nocturnal petrels and visited a portion of a populous albatross colony. The old birds were still hard at work executing that queer "song dance," and in the uncertain light the effect was one long to be remembered. Their white plumage made them conspicuous for a long distance over the stretches near the lagoon. From all sides the sound of their groans and bill-snappings was audible above the continual thin, high squeak of young albatrosses and the moans and caterwauling of shearwaters and petrels. During some quieter spell in the activities of the vocalists far-away groans were borne to us across the placid lagoon, as a reminder that in other parts the good work was still going on. By this time many of the albatrosses had started off fishing, as they seem to do a large part of it after dark, probably toward morning.

It is interesting to note that the antics which have just been described are not limited to this species, but, in a modified form, are practised by *Diomedea nigripes*, and are mentioned also by Rothschild and Hartert† in connection with *Diomedea irrorata* Salvin. Probably all species of the genus exhibit the trait in some form.

A complete article on the work done by the United States Fish Commission in the Laysan Islands will appear in the next number.

The Current Supplement.

A full-page portrait of the late Prof. Theodor Mommsen, perhaps the most prominent German historian of the last century, will be found on the front page of the current SUPPLEMENT, No. 1458. An adequate biographical notice accompanies the portrait. "Ancient Chaldean Irrigation" is the title of an article that will doubtless be of interest to agricultural engineers. An instructive article on Experiments with a New Type of Compound Locomotive in Italy gives the results which have been obtained on the Meridionali Railway. The Wilde lecture before the Manchester Philosophical Society had for its subject the atomic theory. The paper will be published in full, the first installment appearing in this issue. Mr. E. W. Nelson tells much that is instructive about the Agaves, a remarkable group of useful plants. Prof. F. Webster writes on the "Insect Pests of Plants and Their Effect on American Agriculture." Mr. Dugald Clerk, England's foremost authority on gas engines, writes instructively on "Governing Gas and Gasoline Engines."

Electrification of the Park Avenue Tunnel.

The General Electric Company of Schenectady, N. Y., has secured the contract from the New York Central Railroad for the equipment of the lines which run through the Park Avenue tunnel in New York city, with electricity. The work will cost about $12,000,000. For over a year the company has been experimenting with various types of locomotives for the purpose of determining which is the most suited to the needs of the tunnel. The contract includes thirty locomotives, ten steam turbines of 5,000 kilowatts, together with the equipment of a big power plant.

On November 21 the high-speed electrical experiments on the Berlin-Zossen Railroad were terminated for the season. Altogether, a million dollars have been spent simply for the purpose of ascertaining just what a high-speed electrical train can do. A syndicate composed of two great German electrical companies will shortly publish the results which have been obtained—results which will be of the utmost value to electrical engineers the world over.

* Abstracted from "Birds of Laysan and the Leeward Islands, Hawaiian Group," in the U. S. Fish Commission Bulletin for 1903.

* Extract from Avifauna of Laysan, p. III (F. H. von Kittlitz in Museum Senckenbergianum, I, pp. 117 et seq.).

† Novitates Zoologicæ, vi, p. 125.

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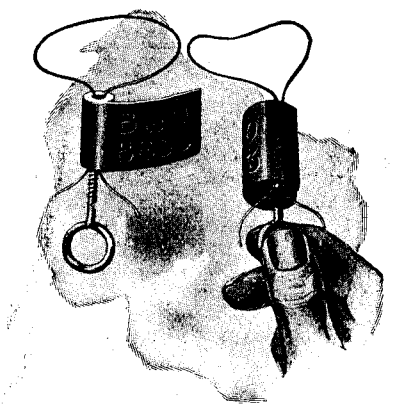

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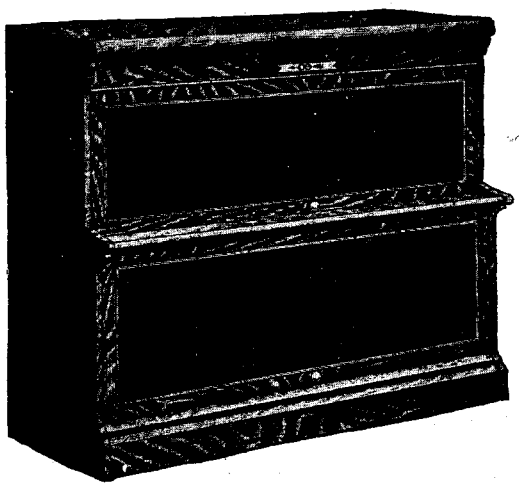

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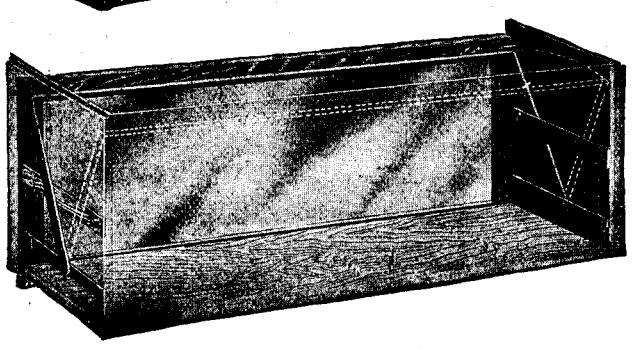

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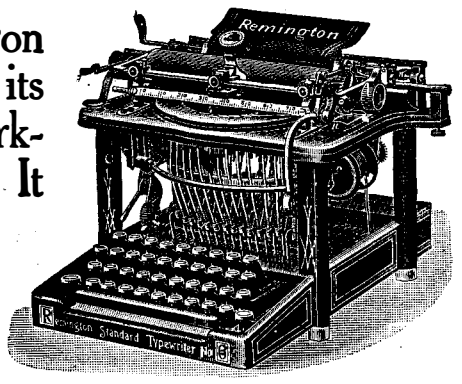

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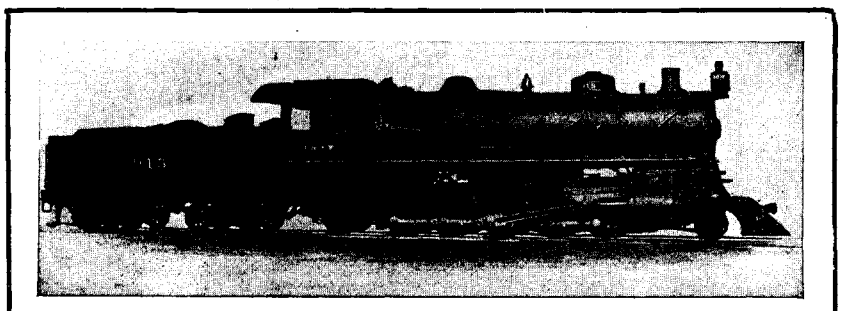

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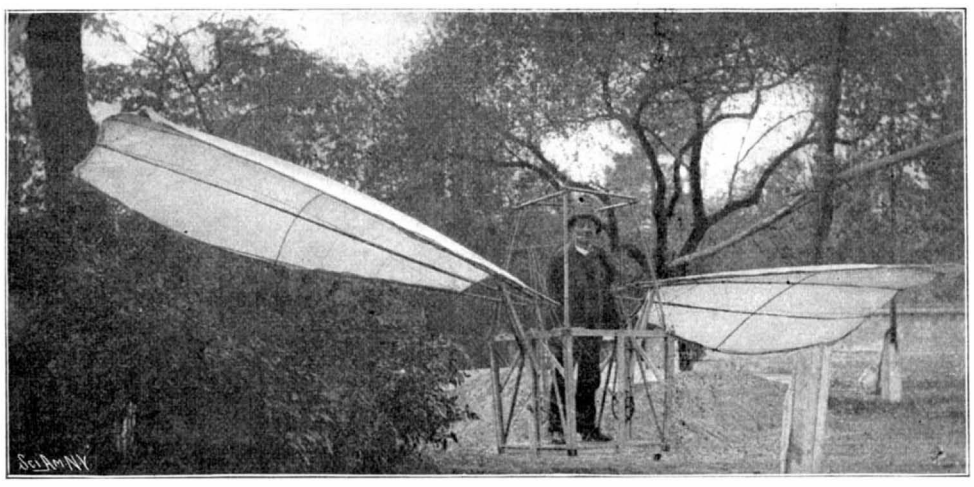
MARCEAU'S "BUTTERFLY."

In the little town of Neuilly, France, lives a certain Emilien Marceau, who is a printer by trade. It happens that the printing business is not particularly brisk in Neuilly, for which reason Marceau must turn to other things in order fully to occupy his mind. From his shop windows he had ample opportunity to watch the birds and butterflies as they flitted by. After he had watched the birds and butterflies for several years, he was seized with the desire to fly. And thus it came about that Marceau joined the ranks of airship inventors. Butterflies fly because they have wings; therefore, a flying machine must have wings, he thought. He built himself a rude car, fitted with outriggers on which wings were pivoted, and coupled up these wings with a man-driven mechanism, consisting merely of a sprocket and chain which gave a reciprocating movement to the wings. With a kind of poetic fitness, or rather unfitness, Marceau christened his machine the "Butterfly." Here is Marceau's lucid account of the "Butterfly's" soaring possibilities:

"My car weighs 61½ pounds; I weigh 165 pounds; total weight, 226½ pounds. I fasten a balloon to my car, capable of lifting 220 pounds. I drive my machine by muscular force alone; and this muscular driving power gives me an additional lifting capacity of 44 pounds. That means I have about 38 pounds to spare. I must rise; my figures are conclusive."

Unfortunately, Marceau has not the wherewithal to purchase a balloon, so that the conclusiveness of his cogent reasoning, however satisfying it may be to himself, is still open to question. Some day he may get his balloon; if he does, he will learn more about gravitation than was ever dreamed of in his philosophy.



MARCEAU'S "BUTTERFLY."

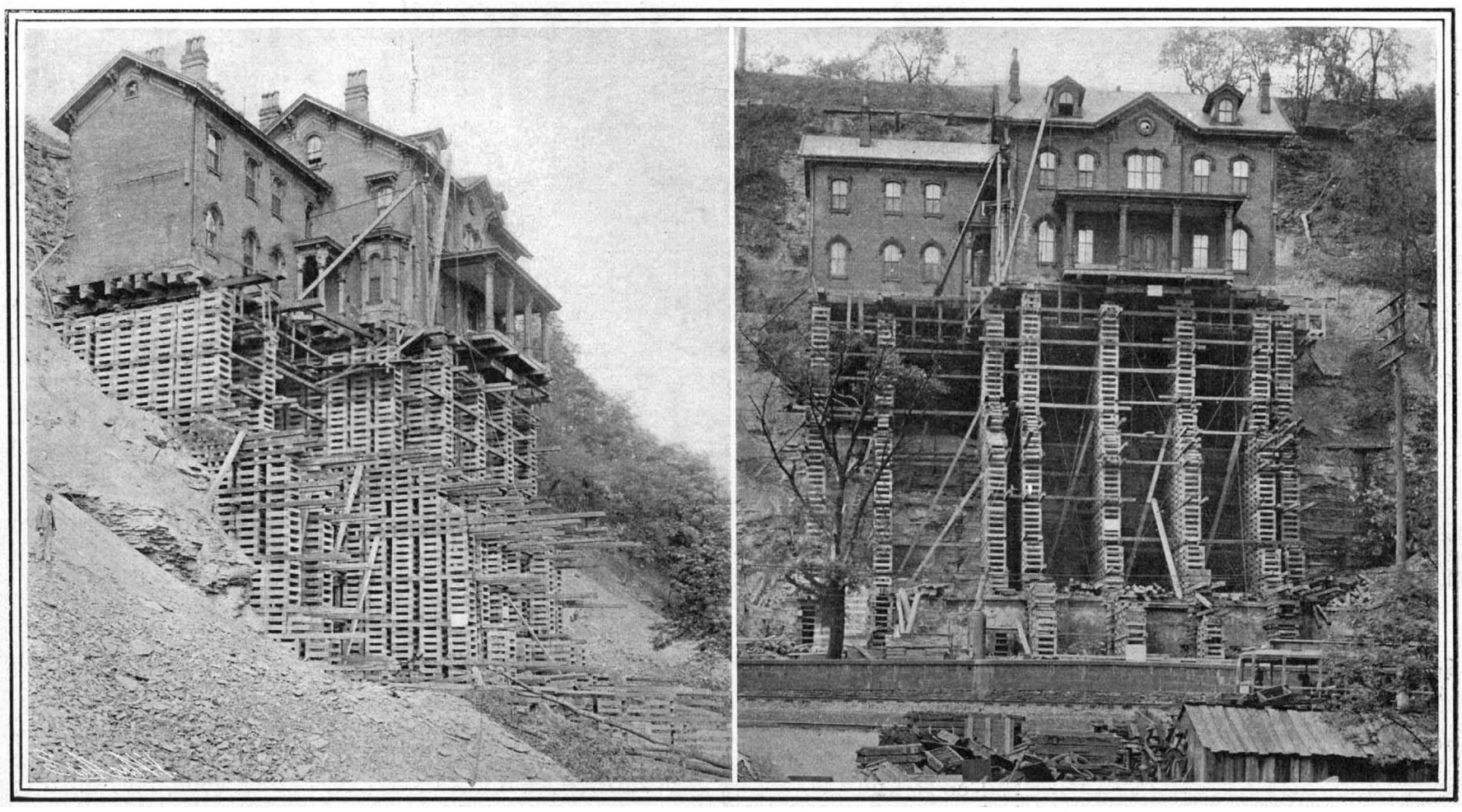
A VERTICAL HOUSE MOVING.

There have been some remarkable feats of house moving chronicled from time to time in the columns of the SCIENTIFIC AMERICAN; but surely the one of which we here present illustrations, in which a fine old mansion was lifted 160 feet from the banks of the Monongahela to the summit of the cliffs above, is the most remarkable of them all. The building, which is known as the Brown mansion, has stood for several generations at the foot of the lofty and precipitous cliffs which line the river at this point. It was built by a Capt. William Brown, father of the present owner, and has been a landmark at Brown's Station on the Baltimore & Ohio Railway for many years. Among the many improvements of their track which are being carried out by the Baltimore & Ohio Railway Company is the straightening out of their line, by the elimination of the sharper curves, especially on those portions of the line which follow the windings of the river. At Brown's Station, where this house was located, the railway company required for improvement purposes the ground on which the building stood; and when the site had been sold to the company, the question arose as to what disposition should be made of the old mansion. At the top of the cliff, 160 feet above the former site of the house, is a fine stretch of orchard land belonging to the present owners of the house, and, largely from sentimental reasons, it was decided to move the building up the face of the cliff and place it on this elevated site, which commands a fine view of the river and the surrounding country. The difficulty of the task will be understood when it is stated that the building measures 85 feet by 40 feet, and weighs about 800 tons. The first operation was to insert eight large timbers, measuring 12 inches by 16 inches, and 85 feet in length, beneath the building, while between these and the structure were laid about 200 7-inch steel needle-beams. While this was going on, the face of the cliff was stepped out into four benches of about 30-foot lift each. The building was then raised a little at a time by hand jacks, and the eight walls of timber cribwork built up beneath it. The blocking was all carefully sized to 6 inches by 8 inches. The cribwork was stiffened in both directions by means of 8 x 8-inch waling pieces, and it was sway-braced by half-inch chains with turnbuckles. When the house had been lifted 30 feet, it was drawn onto the first bench by means of two winches on the top of the cliff, each driven by two horses, a 2-inch line with four-part blocks being used. Another lift of 30 feet was then made to the next bench, and the various operations were repeated, until the house was landed on its new site, 200 feet back from the old site and 160 feet above it. As may well be imagined, a vast amount of timber was required for this work, amounting in all to 20,000 carefully-sized sticks, which required twenty cars to transport them. The actual cost of this house moving is not given out, but it is well understood that it considerably exceeds the original cost of the house itself. We are indebted for our illustrations and particulars to Messrs. John Eichleay, Jr., Company, the contractors for this unique piece of engineering work.

New Iron-Hardening Process.

Phosphorus, as is well known, has the property of imparting a certain degree of surface hardening to iron, but not without producing brittleness. The iron is made to assume a coarse structure, in which the crystals are comparatively loosely bound together. This effect of phosphorus of loosening the coherence of the molecules of the iron greatly facilitates the absorption of carbon by the iron. The carbon rapidly penetrates the iron to a considerable depth, imparting great toughness to the core and nullifying the comparatively slight defect constituted by the inconsiderable brittleness of the surface. Two Prussian inventors apply this principle in their process for hardening iron by heating the same in a tempering powder consisting of organic nitrogenous substances, containing a high percentage of fusible ash and employing phosphorus as the medium for the introduction of carbon into the iron. Without prejudicially affecting the welding properties of the iron, it imparts such a degree of hardness thereto that it can neither be cut nor chipped by the best steel used. In order to harden the surface of about 200 kilogrammes (441 pounds) of iron to a depth of 1 millimeter (.0394 inch) by means of this process, the pieces should be imbedded in a retort, muffle, or the like, in bone dust, to which is added a mixture of 300 grains of yellow prussiate, 250 grains of cyanide of potassium, and 400 grains of phosphorus. The receptacle is well closed, luted with clay, etc., and raised to a clear red or white heat, whereupon the material treated is immersed in a glowing condition in a water or other bath.—From Oliver J. D. Hughes, U. S. Consul-General, Coburg, Germany.

With a view to stimulating invention and of inducing inventors to effect improvements in existing appliances, the Industrial Society of Mulhouse in Alsace has issued a programme of prize medals which it is prepared to award in February, 1904, for (1) a new type of fixed boiler to utilize more than 80 per cent of the heat generated in the firebox; (2) an apparatus to register the total effective work of steam engines; (3) a gas engine to utilize poor gas and developing 250 horse power and upward; (4) improved methods of steam raising, whether by gas, mechanical stoking, or other means; and (5) improved wool combing and carding machinery. Copies of the programme and any further information can be obtained from the secretary of the society at Mulhouse.



This old mansion, measuring 85 by 40 feet, and weighing 800 tons, was raised from the banks of the Monongahela River to the summit of the bluff, a vertical lift of 160 feet.

VERTICAL HOUSE MOVING.

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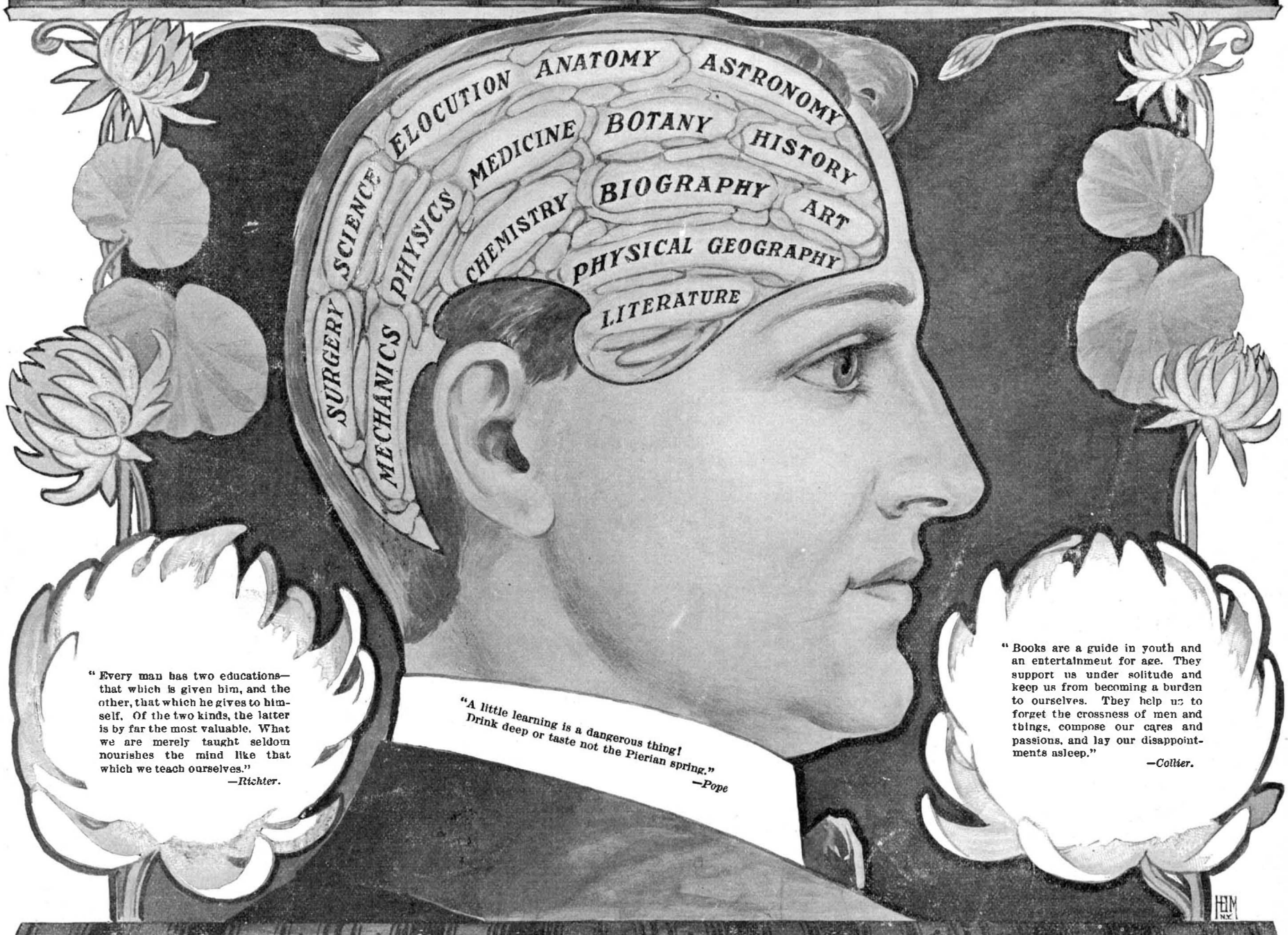
A Head Full of Knowledge & Inspiration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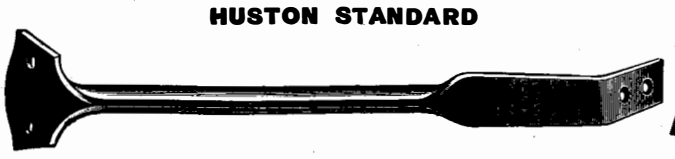

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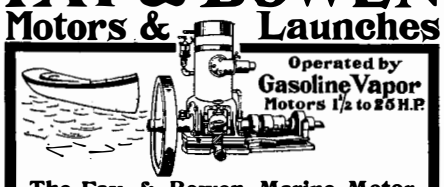

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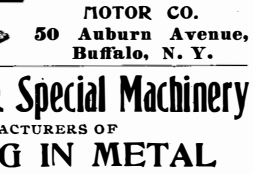

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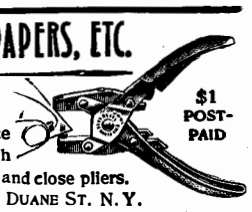

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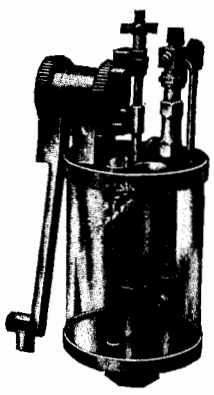

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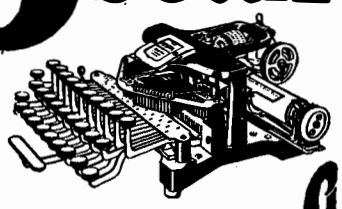

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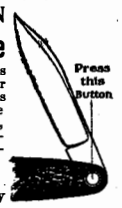

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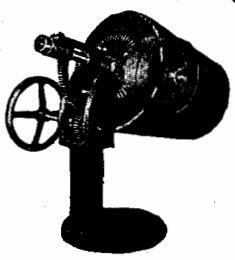

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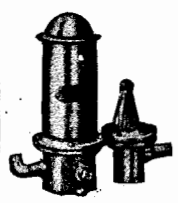

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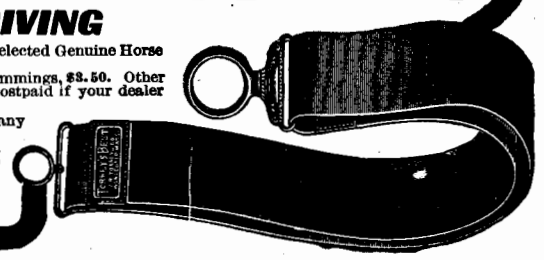

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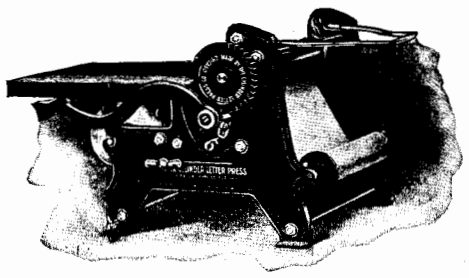

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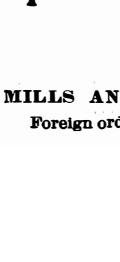

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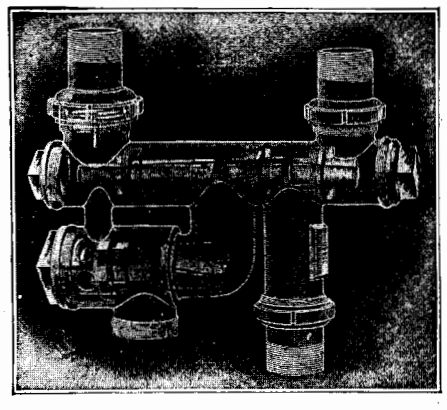

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(9238) E. C. H. says: My boat is 32 ft.x4 ft. x 12 inches; engine, 3½x6x6; revolutions, 380 to 420; steam, 125 pounds; wheel, 27½ inches; pitch, 37 inches. Speed over measured mile in slack water, 11.39 miles with full stroke. Normal speed, 9 to 10 miles with ¾ cut-off. I. H. P. (cards) under 9. Vol. 26 inches to 27 inches. This may interest E. T. R., No. 9225 of Notes and Queries, in SCIENTIFIC AMERICAN, November 14.

(9239) C. F. F. says: Have you any publication that gives a more explicit explanation of the Wimshurst induction machine than is to be found in Hopkins's "Experimental Science"? I regret to say a machine that I constructed according to his instructions refuses to work. Have made one radical change from his specifications, by using large gramophone disks in place of glass. Do you suppose that is the cause of my failure? Have used the rubber disks before, and obtained excellent results in condensers, and supposed that same could be used for the above purpose. A. We think it strange that you should say you have constructed a Wimshurst machine according to Hopkins's "Experimental Science," and it will not work, when in the next sentence you say you have used a very different plate from the directions in "Experimental Science." We think if you had used glass plates as directed, you would have had success. We see no reason why a smooth ebony plate might not be used on the machine, but should not expect success with a rough plate, as we suppose the gramophone plate to be. In condensers, the rubber plates act only as insulators. In a machine their office is very different. An induction takes place through them, and they are charged and discharged as they revolve. In making a new article from instructions, it is most desirable to follow the instructions implicitly. We recommend, and can supply at once, the new edition of Gray's "Electrical Influence Machines," which describes the construction of Holtz and Wimshurst machines. Price $2 by mail.

(9240) J. E. H. says: As a constant reader of your valuable paper, I take the liberty of asking you the following questions, which I trust you will be willing to answer, not only for my own benefit, but for all your interested readers: Is there such a thing on the market as a perfect rotary engine? If so, kindly state wherein they are superior to the ordinary types of to-day. A. Replying to your question regarding a perfect rotary engine, we would say that there is no perfect engine of this character on the market. A rotary engine has the advantage of not requiring the reciprocating parts of the ordinary steam engine, and therefore may be perfectly balanced. In some cases this would be an undoubted advantage. No thoroughly successful engine of this type, however, has been placed on the market, owing to the difficulty of controlling the admission, expansion, and release of steam by means of simple mechanism. The steam turbine has the advantages of the rotary engine, and is now being built in this country.

(9241) W. A. A. says: Please give me rule for determining proportion of air and coal gas, for best results with atmospheric burner. A. A rule for determining the proportion of air for the perfect combustion of coal gas is as follows: It is first necessary to know the chemical analysis of the gas, because the combustion of coal gas varies much in different places. The three principal constituents which take part in the combustion are, first, hydrogen, second, carbon, third, carbon oxide (CO). In order to determine the amount of oxygen for each of these three constituents, multiply the number of parts of hydrogen by 8, multiply the number of parts of carbon by 32-12, multiply the number of parts of CO by 16-28; add these three quantities together, and it will give the weight of oxygen needed; then multiply this amount of oxygen by 5, and it will give the weight of air needed for the perfect combustion of the coal gas. As a rule, from 30 per cent to 50 per cent excess of air is required for the best results. At atmospheric pressure, one pound of air is equivalent approximately to 13 cubic feet.

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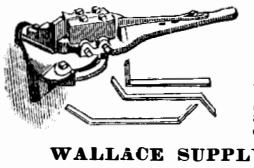

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NEW BOOKS, ETC.

AMERICAN HISTORY AND ITS GEOGRAPHIC CONDITIONS. By Ellen Churchill Semple. Boston and New York: Houghton, Mifflin & Co. 1903. 8vo. Pp. 466. Price $3.

In this excellent though not too scholarly work, the author has traced in no uncertain manner what may be called the influence of the geography of this continent upon the history of the United States. In other words, she has shown the effect of the explorations of the earlier adventurers, the consequent spread of geographical knowledge among the people of the East, and the resulting growth of the United States to a continental power. One fact stands out prominently in this geographical estimate of our position, and that is that our course of acquisition has ever trended westward; that it has overstepped the boundaries of the Pacific, has reached Hawaii and the Philippines, and now seems to have acquired no unimportant position in China. A chain of historical events has determined that the commercial outlet of this country is to be found in the Far East. Excellent bibliographies are to be found at the end of each chapter, which simplify the problem of retracing the ground the author has covered.

LE POINT CRITIQUE DES CORPS PURS. Par E. Mathias. Paris: G. Naud. 1904. 8vo. Pp. 255.

This little volume, as its preface informs us, is a natural development of the author's report to the International Physical Congress held in 1900. It is an exhaustive exposition of all the facts which tend directly or indirectly to the study of the critical point of pure bodies. It must be confessed that the author has proceeded with considerable impartiality. He himself, however, seems to favor the liquidogenique idea of Traube.

JAHRBUCH FÜR DAS EISENHUTTENWESEN. Ergänzung zu Stahl und Eisen. Ein Bericht über die Fortschritte auf allen Gebieten des Eisenhüttenwesens im Jahre 1901. Im Auftrage des Vereins deutscher Eisenhüttenleute bearbeitet von Otto Vogel. II. Jahrgang. Düsseldorf: August Bagel. 1903. Price $3.50.

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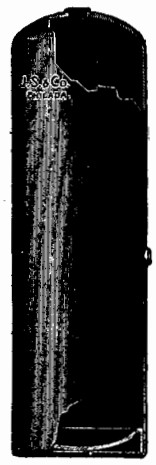
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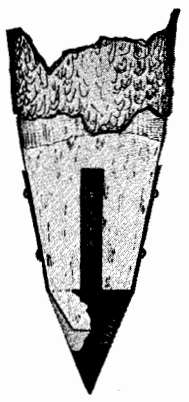
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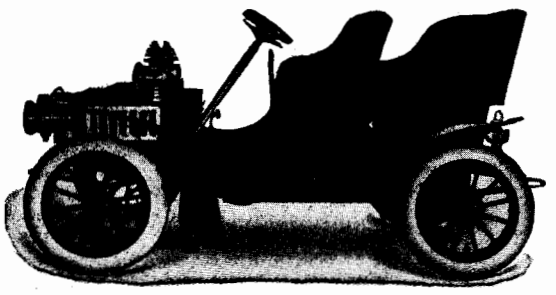
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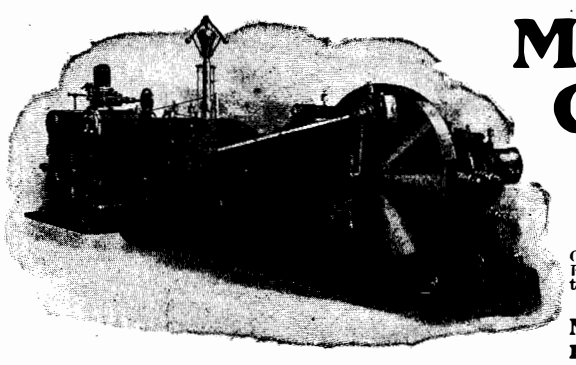
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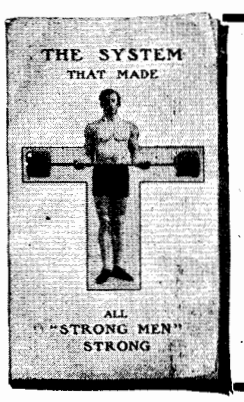

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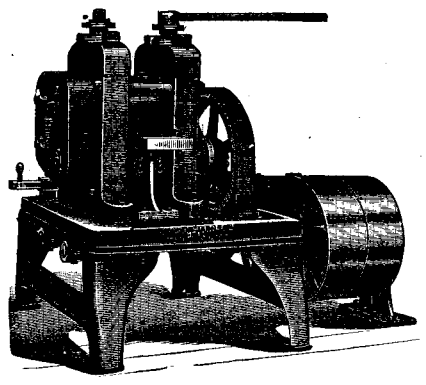

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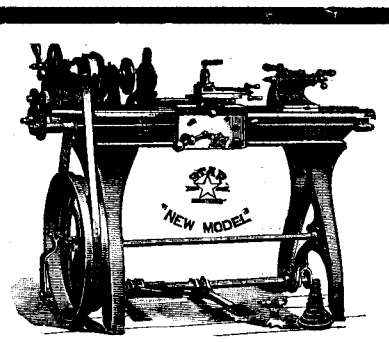

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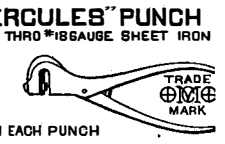

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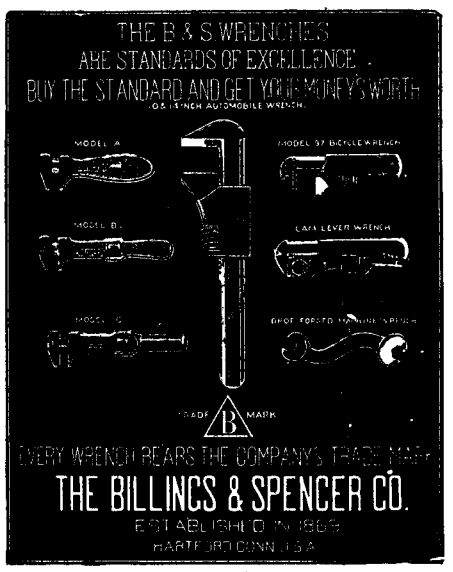

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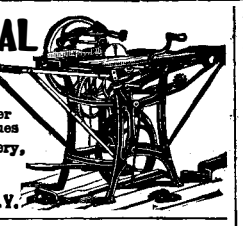

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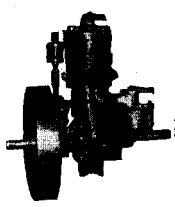

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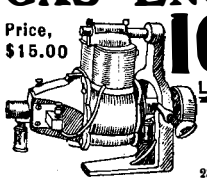

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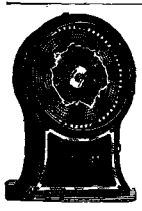

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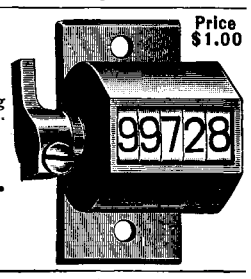

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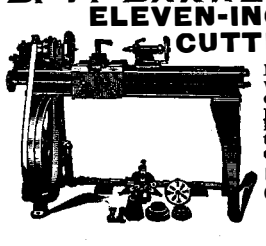

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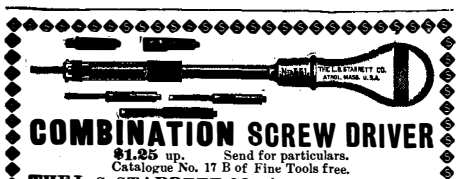

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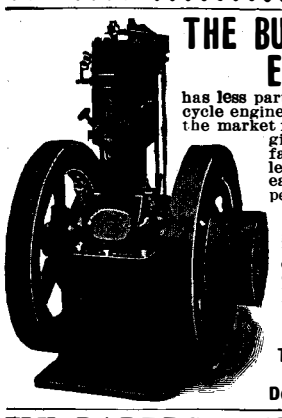

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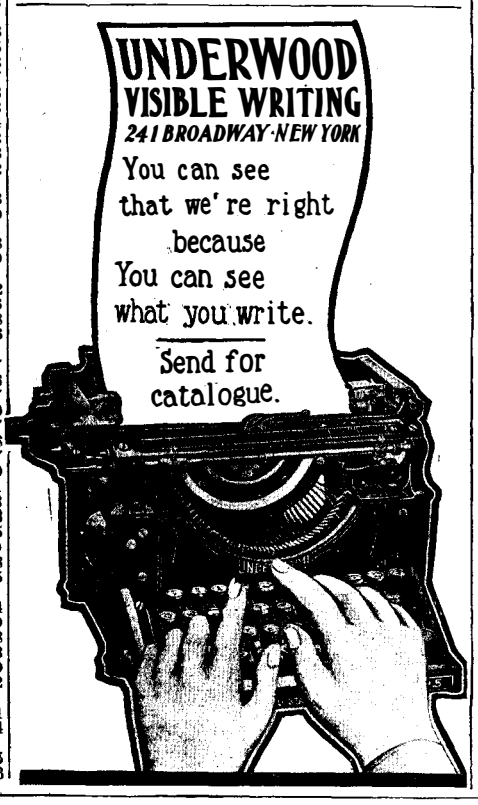

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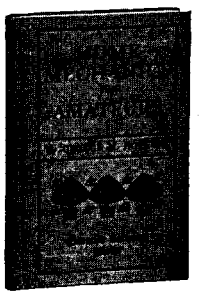

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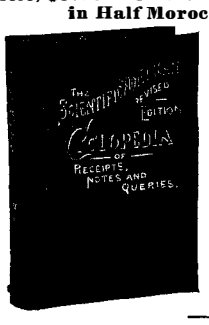

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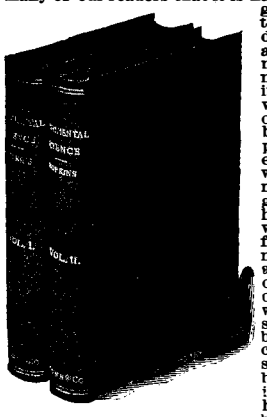

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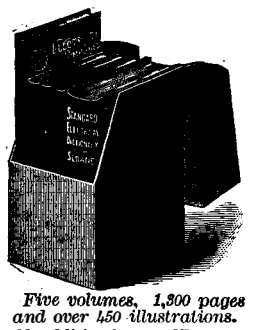

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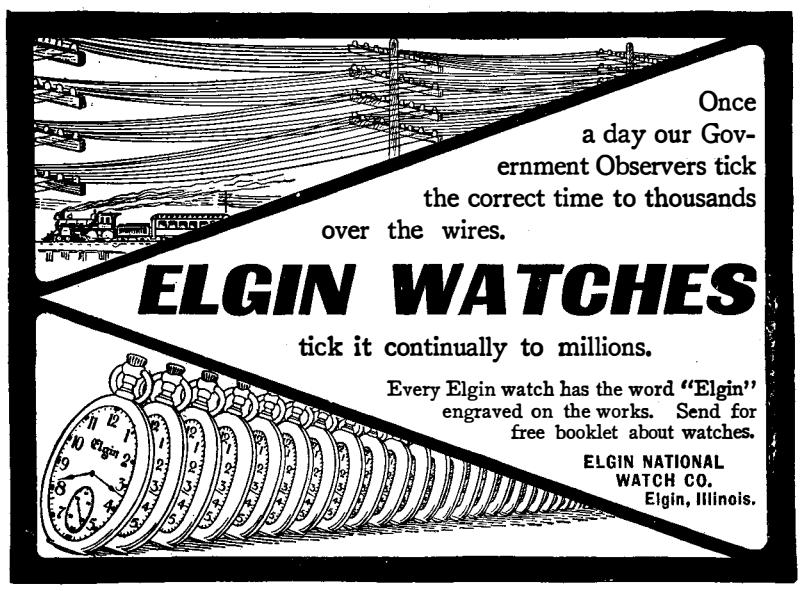

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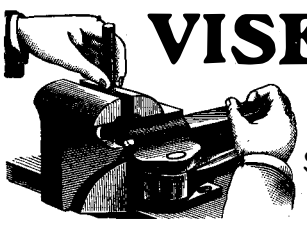

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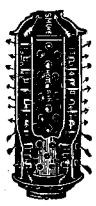

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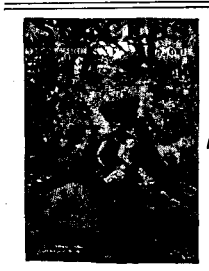

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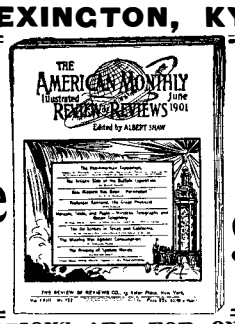

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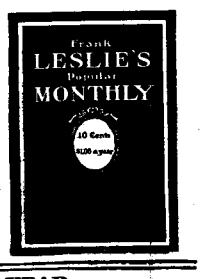

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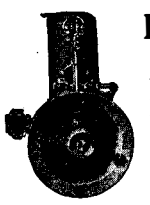

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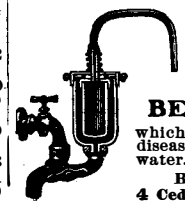

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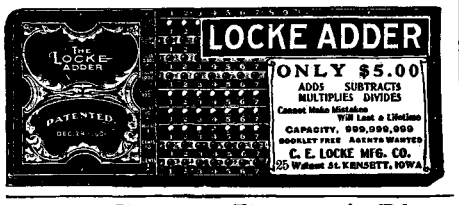

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Water power apparatus, J. F. Williams	745,945
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Weaner and udder protector, calf or colt, Cunningham & Spear	745,419
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Wire stitching machine feed device, W. Shafer	745,917
Wire stretcher, L. A. Preston	745,662
Wrapping machine, J. H. Felmlee	745,810
Wrench, B. McNiel	745,369
Zinc, electrolytic refining of, H. Paweck	745,378

DESIGNS.

Billiard table, J. Ehrenpreis	36,662
Bottle, A. N. Ritz	36,656
Brooch, button, or buckle plate or similar article, S. A. Keller	36,649, 36,650
Brooch plate or similar article, E. F. Rueckert	36,648
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Ciclometer casing, J. Alexander	36,657
Dress ornament, fancy, L. M. Keigher	36,664
Glove, F. Schmidt	36,665
Silverware or similar articles, handle for, H. Weber	36,652, 36,653
Silverware or similar articles, lip for, H. Weber	36,655
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Stove, O. D. & B. Hunt	36,658
Wagon body, G. H. Barschow	36,659 to 36,661

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Bluing, M. C. O'Neill	41,571
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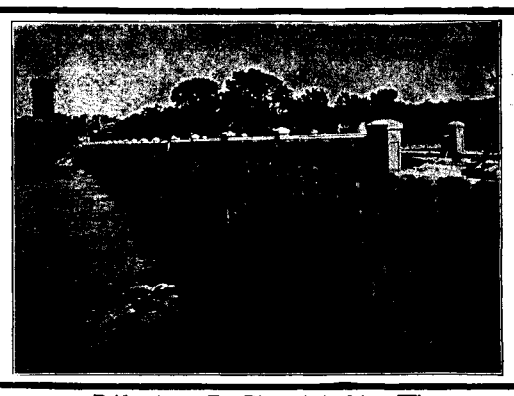

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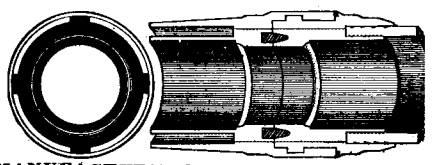

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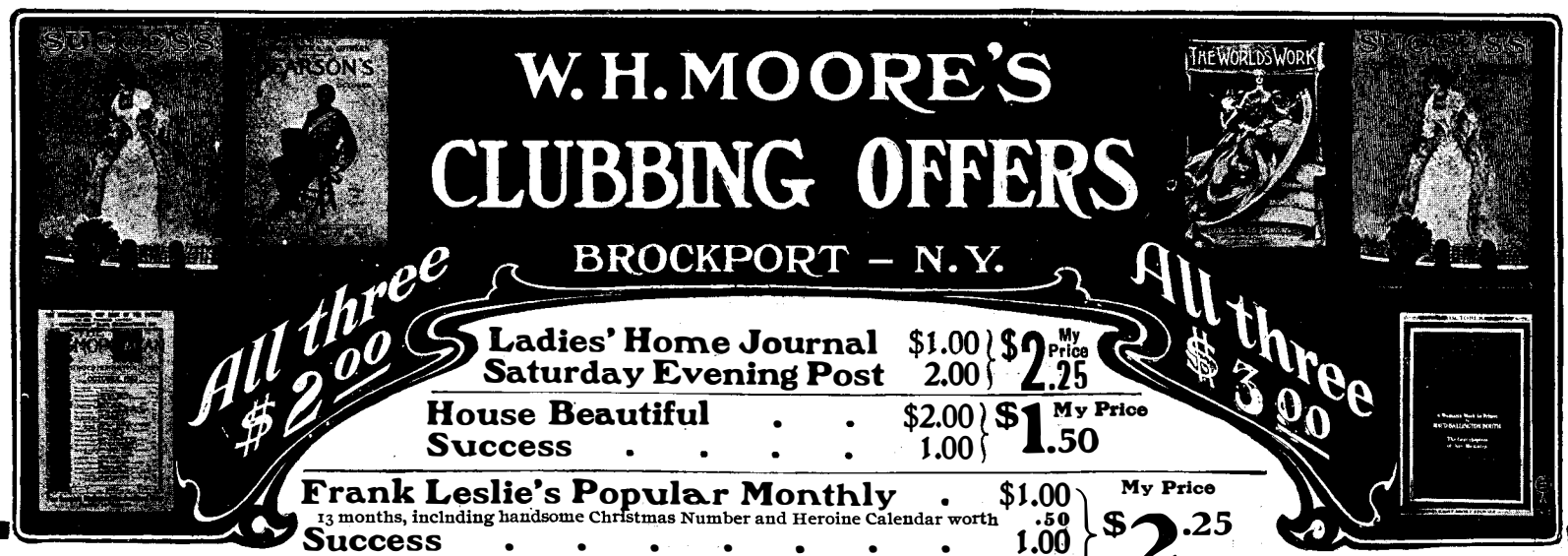

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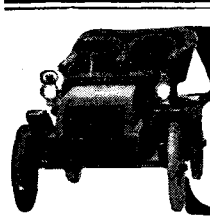

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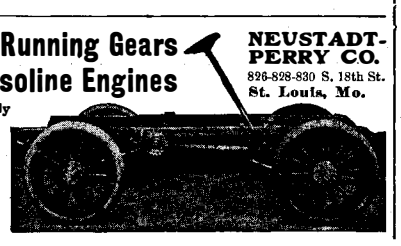

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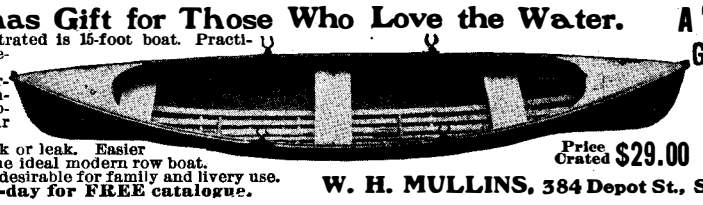

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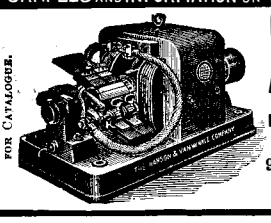

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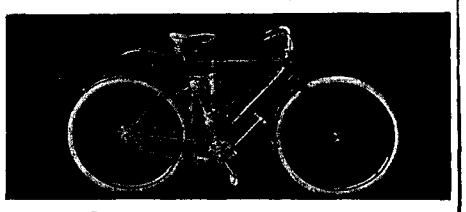

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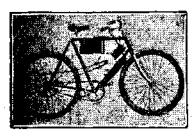

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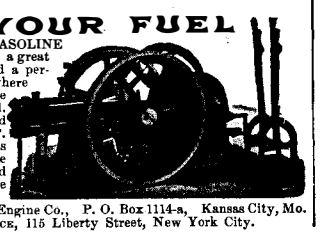

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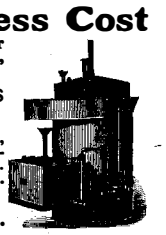

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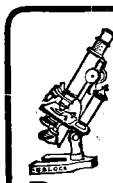

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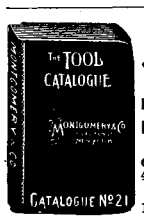

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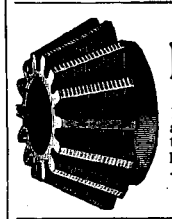

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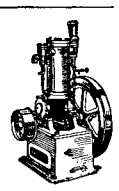

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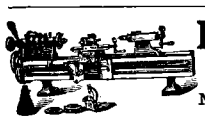

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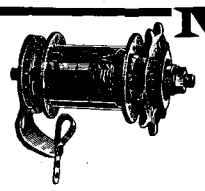

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